SR 3 MP 58.49 Spring Creek to Hood Canal (WDFW ID 990395): Preliminary Hydraulic Design Report

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ROLES AND RESPONSIBILITIES FOR THIS PRELIMINARY HYDRAULIC DESIGN

The roles and responsibilities of the key individuals in developing this Preliminary Hydraulic Design (PHD) are defined as follows for the Olympic Region GEC:

PHD Lead PE
Responsibility: Water Resources Professional Engineer in responsible charge of this Hydraulic Design Report, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices.

Authoring Firm PHD QC Reviewer(s)
Responsibility: Qualified independent individual(s) responsible for the detailed checking and reviewing of hydraulic and stream design documents prepared by the authoring firm, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices. Before submittal to the GEC, the authoring Firm Quality Control (QC) Review shall be performed in accordance with the QC methods identified in the quality assurance document Technical Verification Form. The QC methods are defined in the Olympic Region GEC Quality Management Plan Section 5.3 and the Quality Management Plan Supplement developed specifically for Y-12554 Task AC.

Olympic Region GEC Fish Passage/Stream Design Advisor
Responsibility: Water Resources Professional Engineer providing mentorship, process oversight, quality check issue resolution, and recommendations in the approach to hydraulic analysis and design performed by the **PHD Lead PE**. Before submittal of draft deliverables from the GEC to either the PHD Lead or WSDOT Headquarters, the Olympic Region GEC Fish Passage/Stream Design Advisor will review and refine GEC comments and confirm GEC comment resolution by the **PHD Lead PE**.

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1 Introduction

To comply with United States et al. vs. Washington et al., No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1 through 23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 3 crossing of Spring Creek to Hood Canal at milepost (MP) 58.49 within WSDOT's Olympic region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 990395) and has an estimated 4,728 linear feet of habitat gain (WDFW 2000).

Per the federal injunction and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full-span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing using the stream simulation design methodology due to the floodplain utilization ratio (FUR) being less than 3.0.

The crossing is located in Kitsap County, 1 mile northeast of Four Corners, Washington, in WRIA 15. SR 3 runs in a north-south direction at this location and is about 0.25 mile from the confluence with Hood Canal. Spring Creek generally flows from east to west, beginning approximately 1.5 miles upstream of the SR 3 crossing (Figure 1). Spring Creek is also referred to as Hudson Creek in some resource documentation.

The proposed project will replace the existing 36-inch-diameter, 119-foot-long, precast concrete pipe with a structure designed to accommodate a minimum hydraulic width of 18 feet. The proposed structure is designed to meet the requirements of the federal injunction using the stream simulation design methodology, as described in WDFW's *Water Crossing Design Guidelines* (WCDG; Barnard et al. 2013). This design also meets the requirements of WSDOT's *Hydraulics Manual* (WSDOT 2022b).

Structure type is not being recommended by WSDOT Headquarters (HQ) Hydraulics and will be determined by others at future design phases.

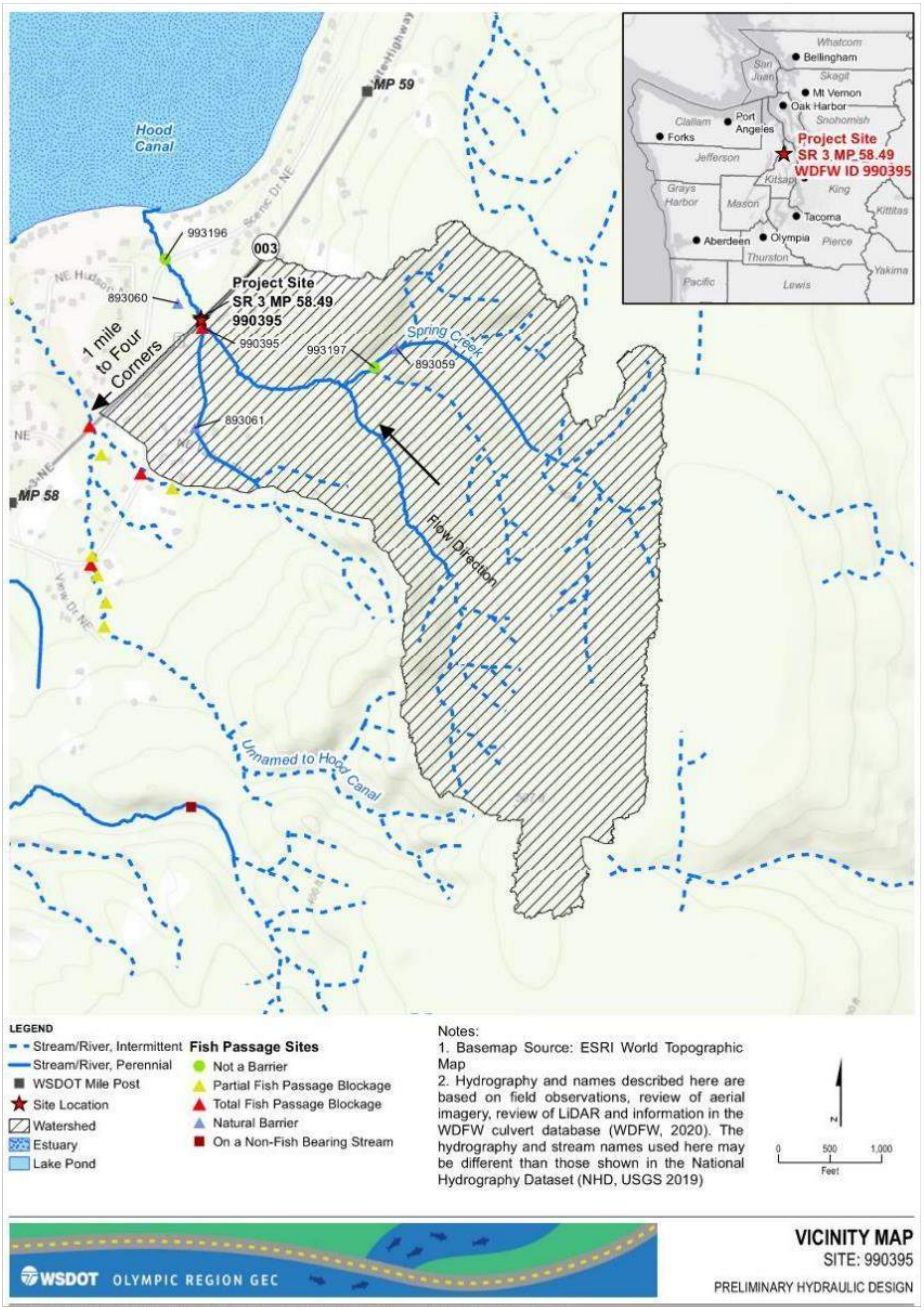

Figure 1: Vicinity map

2 Watershed and Site Assessment

The existing watershed was assessed in terms of land cover, geology, regulatory floodplains, fish presence, site observations, wildlife crossing priority, and geomorphology. This was performed using a site visit and desktop research with resources such as the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and WDFW and past records like observations, maintenance, and fish passage evaluation.

2.1 Site Description

The July 2000 WDFW Level A Culvert Assessment Report found that the existing culvert crossing is a full fish barrier due to slope (1.79 percent) with a 0 percent passability. Field observations indicate that the size of the culvert also likely limits transport of debris—both sediment and large woody material (LWM). Interruption of these processes results in moderate degradation of available fish habitat downstream by starving downstream reaches of sediment and LWM. The 2022 WSDOT survey measured the actual culvert slope at 4.0 percent (WSDOT 2022a). WDFW's report identified this area as a reach that could gain 11,776 square feet of spawning habitat, 16,986 square feet of rearing habitat, and a river length of 4,728 feet (0.9 mile) upstream of the crossing by improving the SR 3 crossing (WDFW 2000).

Culvert inspection reports are unavailable for this crossing as confirmed by WSDOT. There are no records of repairs, cleaning, or Level 2 inspections for this culvert. Additionally, this site is not classified as a Chronic Environmental Deficiency or failing structure by WSDOT HQ Hydraulics.

The project is not within a special flood hazard area or mapped FEMA floodplain, as shown in Appendix A. The area is designated as Zone X - area of minimal flood hazard (FEMA 2017).

2.2 Watershed and Land Cover

Spring Creek flows from east to west, crossing SR 3 at MP 58.49 before entering Hood Canal approximately 0.25 mile downstream of the crossing. Spring Creek includes minor (unnamed) tributaries upstream of the SR 3 crossing, including one minor tributary that confluences just upstream of the SR 3 crossing. Gridded light detection and ranging (LiDAR) topography was used to delineate the majority of the watershed with an area of 409 acres (0.64 square mile). The site neighbors a separate WSDOT preliminary hydraulic design (PHD) (WDFW ID 991240) that was developed by PACE Engineering; the boundary delineation was determined collaboratively with Jacobs Engineering Group Inc. (Jacobs, the design team) and is in alignment on adjoining boundaries. Figure 2 shows the watershed map for Spring Creek.

The Spring Creek watershed ranges from elevations of 475 feet to 75 feet using the NAVD88 (North American Vertical Datum of 1988) vertical datum. The invert elevations at the crossing are approximately 50.2 feet on the upstream end and 45.5 feet on the downstream end. Most of the watershed consists of high-sloped terrain with low-sloped narrow valley bottoms (Figure 3). Land cover was evaluated using the National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium [MRLC] 2019a) and visual interpretation of aerial imagery (ESRI n.d.) (Figure 4). Currently, most of the watershed is forested, with some single-family residences along SR 3.

Review of historical National High Altitude Photography aerial photography (USGS 2018) in the area shows that the watershed had significant logging activities around 1985, which may have contributed to sedimentation of streams and loss of suitable fish habitat; however, no major logging sites were observed since this time. In the past 5 years, an approximately 16-acre logged area has been identified at the upper edge of the watershed. Due to the size and location of this area, it is assumed to have no impact on the condition of Spring Creek and will not be included in the land cover data. The landcover is about 91.3 percent forest (consisting of evergreen, mixed, and deciduous forests), with the remainder identified in Table 1. Total impervious area is approximately 1.2 percent of the watershed, based on analysis of the Impervious Dataset National Land Cover Dataset (MRLC 2019b). Since there is a small percentage of impervious area, it is unlikely that large rain events will produce “flashy” runoff expressed at the crossing.

Table 1: Land cover

Land cover class	Basin coverage (percentage)
Barren Land	0.2
Deciduous Forest	6.0
Developed, High Intensity	0.1
Developed, Low Intensity	3.3
Developed, Medium Intensity	0.1
Developed, Open Space	2.0
Evergreen Forest	72.0
Hay/Pasture	0.1
Herbaceous	1.7
Mixed Forest	13.3
Shrub/Scrub	1.2

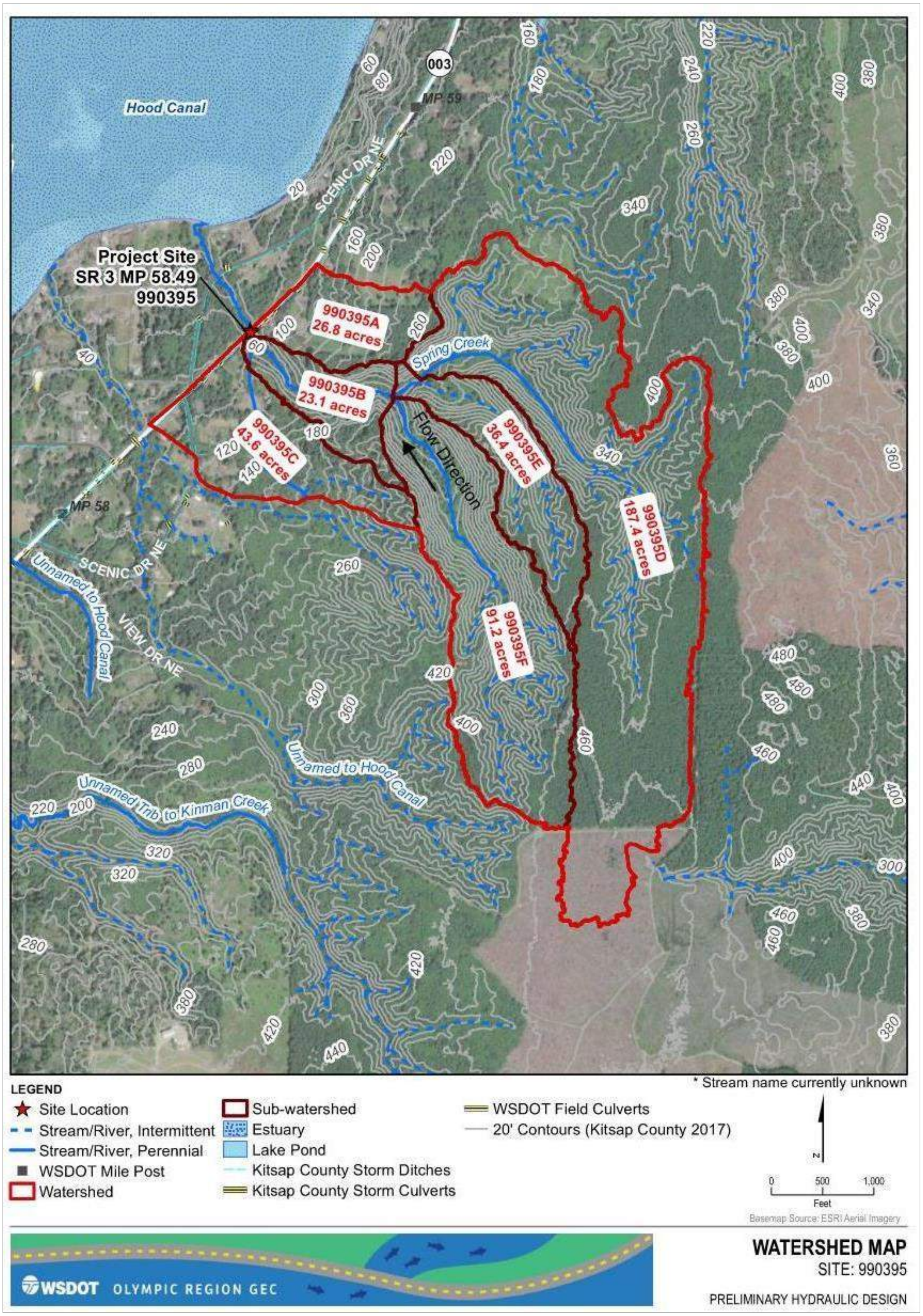

Figure 2: Watershed map

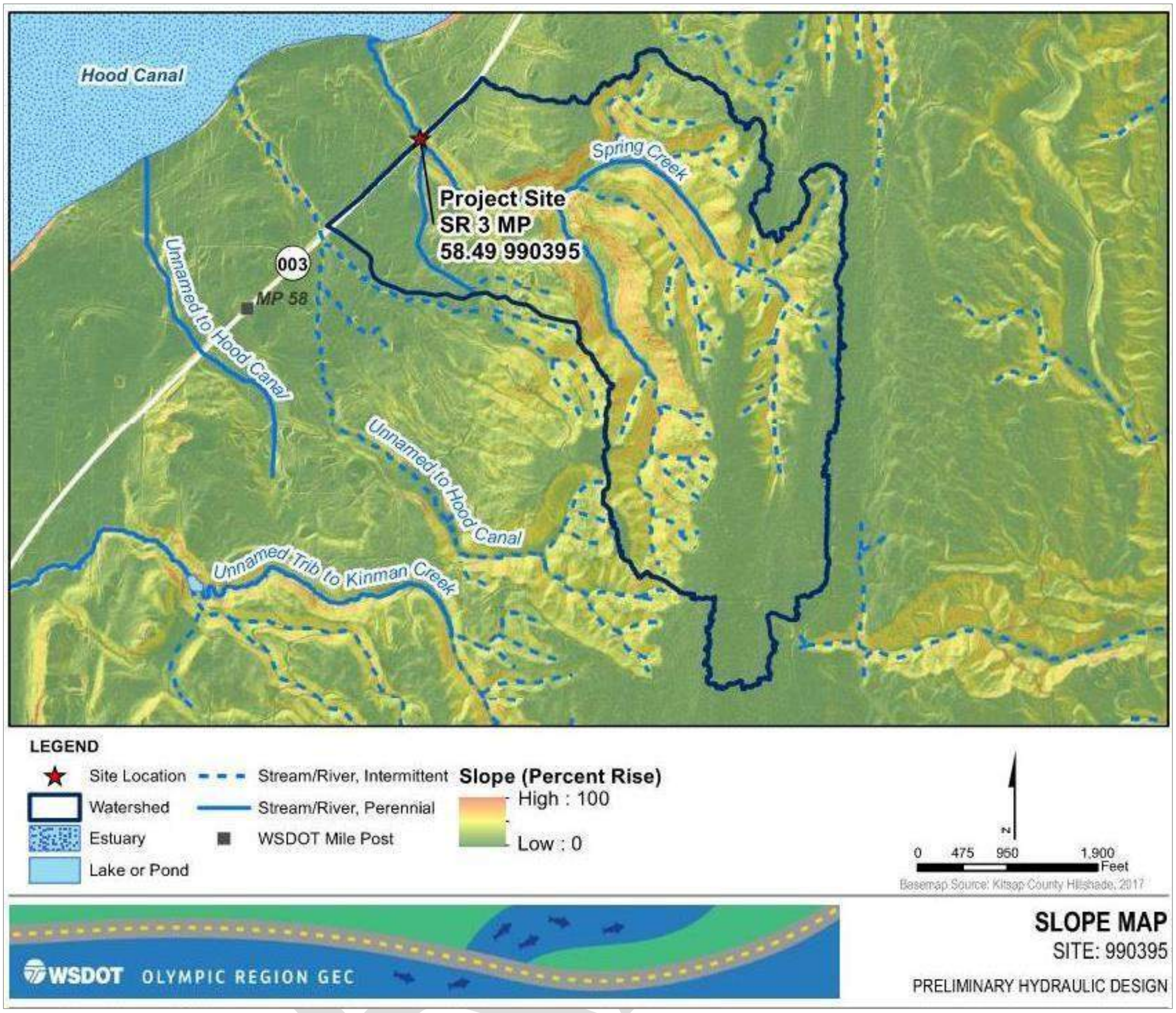

Figure 3: Existing slopes

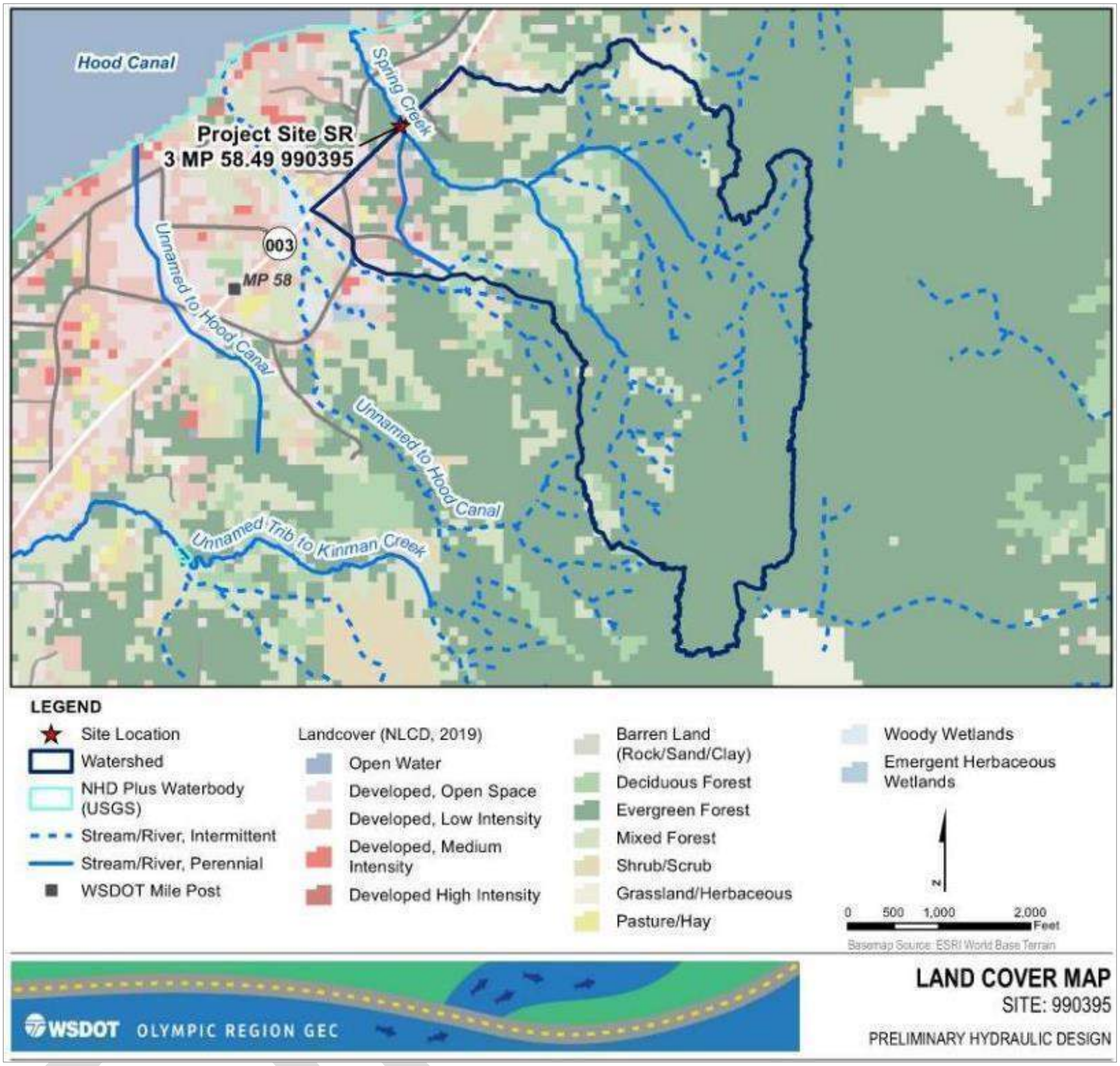

Figure 4: Land cover map (MRLC 2019b)

2.3 Geology and Soils

Spring Creek drains a basin composed primarily of Pleistocene glacial deposits (Figure 5; Natural Resources Conservation Service, U. S. Department of Agriculture [NRCS USDA] 2021). In the upper basin, the valley walls and floor are mapped as glacial drift, which in this area is identified as recessional outwash, consisting of unconsolidated sands and gravels. This drift provides an abundant source of sediment to the stream, which may contribute to fine sediments in the bed material. Most of the downstream basin, and the ridges of the upper basin, consists of glacial till, a glacial deposit that has been consolidated by the weight of overriding glacial ice, and is less erodible and more difficult for water to infiltrate, promoting rapid runoff. The underlying geology and surrounding soil have been accounted for in the design of the stream channel in that the design will attempt to mimic the sediment supply and rely on underlying geology for cobble recruitment.

A brief examination of aerial photographs (ESRI n.d.) did not reveal evidence of recent significant mass-wasting, and no fresh scarps were observed in the area mapped as mass-wasting. However, LiDAR imagery (ESRI n.d.) indicates the presence of landslide scarp upstream of the crossing. The landslide debris may contribute abundant fine sediment to the stream (Figure 6). The landslide scarp is not visible on aerial photographs, indicating that the slide is likely older than the trees growing on it and is no longer active. No bedrock was observed during Jacobs' fieldwork on November 30, 2021.

Soils in the Spring Creek Basin consist primarily of Indianola-Kitsap complex, consisting of loamy sand and silt loam, a moderately well-drained soil that is generally formed from lacustrine deposits (Figure 7; NRCS USDA 2021). Soil types and the underlying geology (Figure 7), along with land use and cover, were used to develop a hydrologic model of the basin, discussed in Section 3.

A geotechnical scoping memorandum (WSDOT 2022c) is available for this crossing and was consulted during preparation of this section. A single borehole was prepared on the downstream side of SR 3, on the right streambank approximately 10 feet away from the roadway. The borehole is not within the active stream channel. The boring results indicate loose, brown, sandy gravel to gravelly sand throughout the boring. Driving resistance was 5-foot drives to 25 feet, double drives to 40 feet, and then 5-foot drives to 60 feet (bottom of hole). Jacobs will coordinate with the HQ geotechnical scoping lead to determine if additional geotechnical data collection is warranted to evaluate lateral migration and long-term degradation. Further discussion on lateral migration is discussed in Section 7.1.

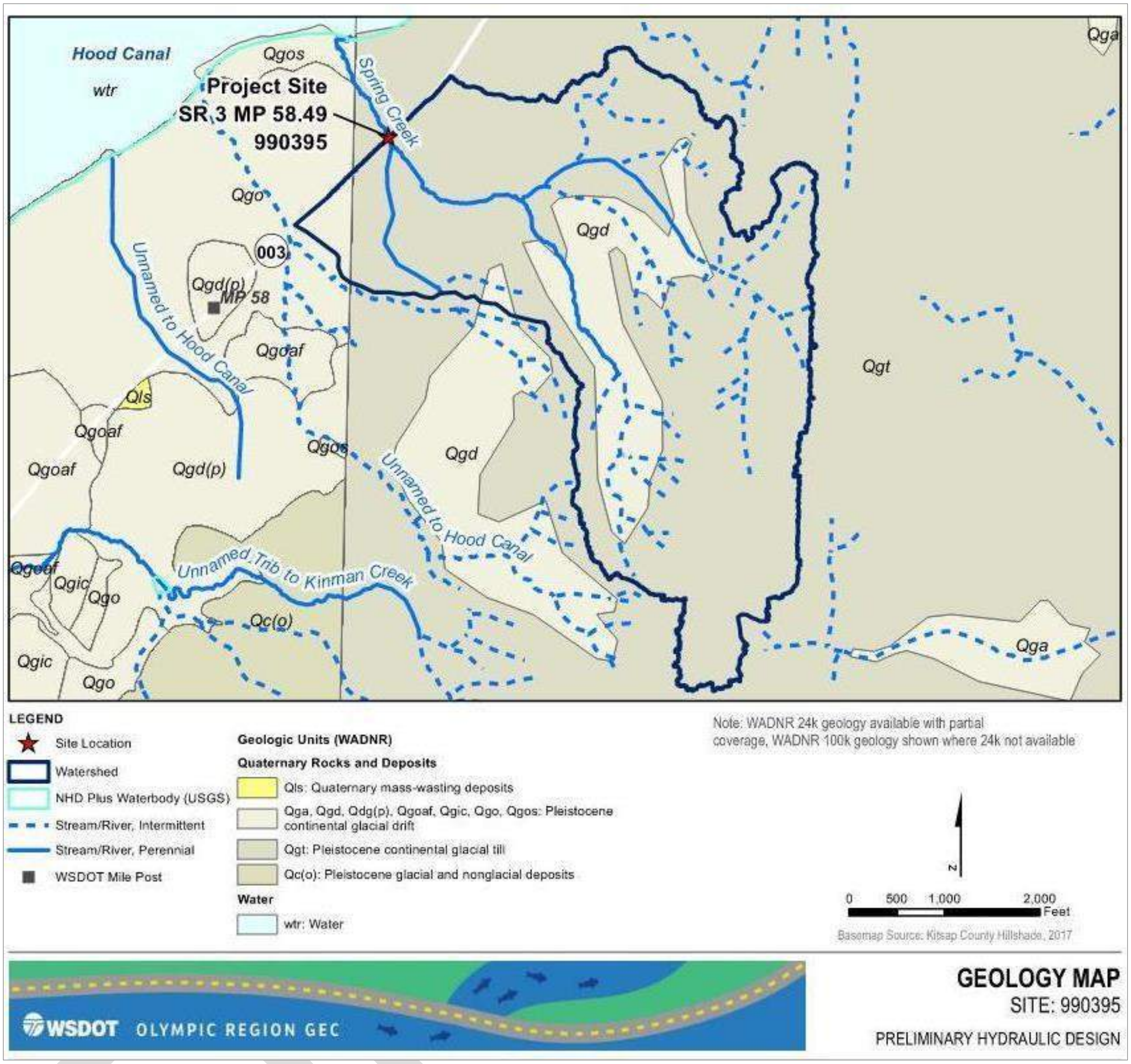

Figure 5: Geologic map

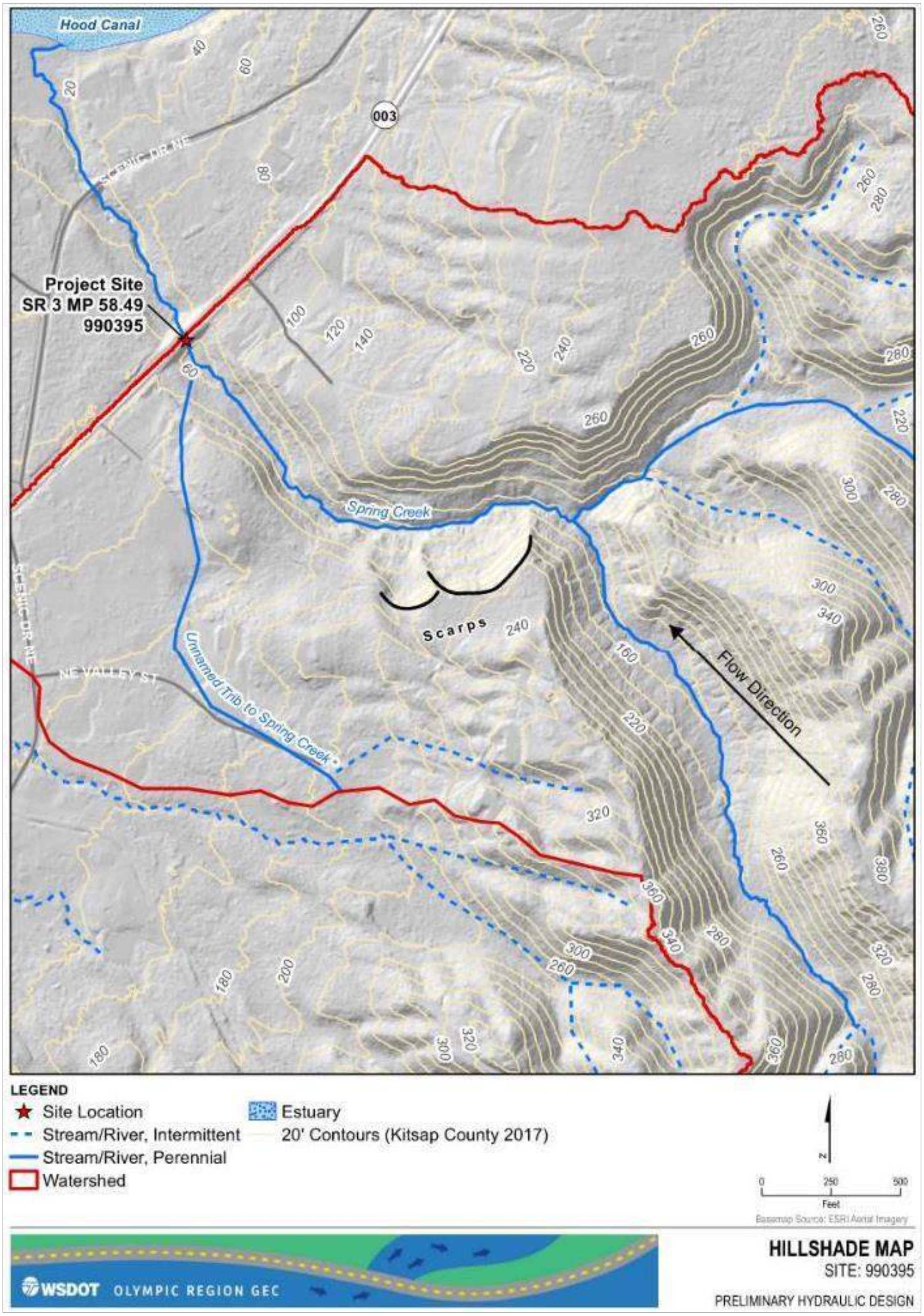

Figure 6: Hillshade map

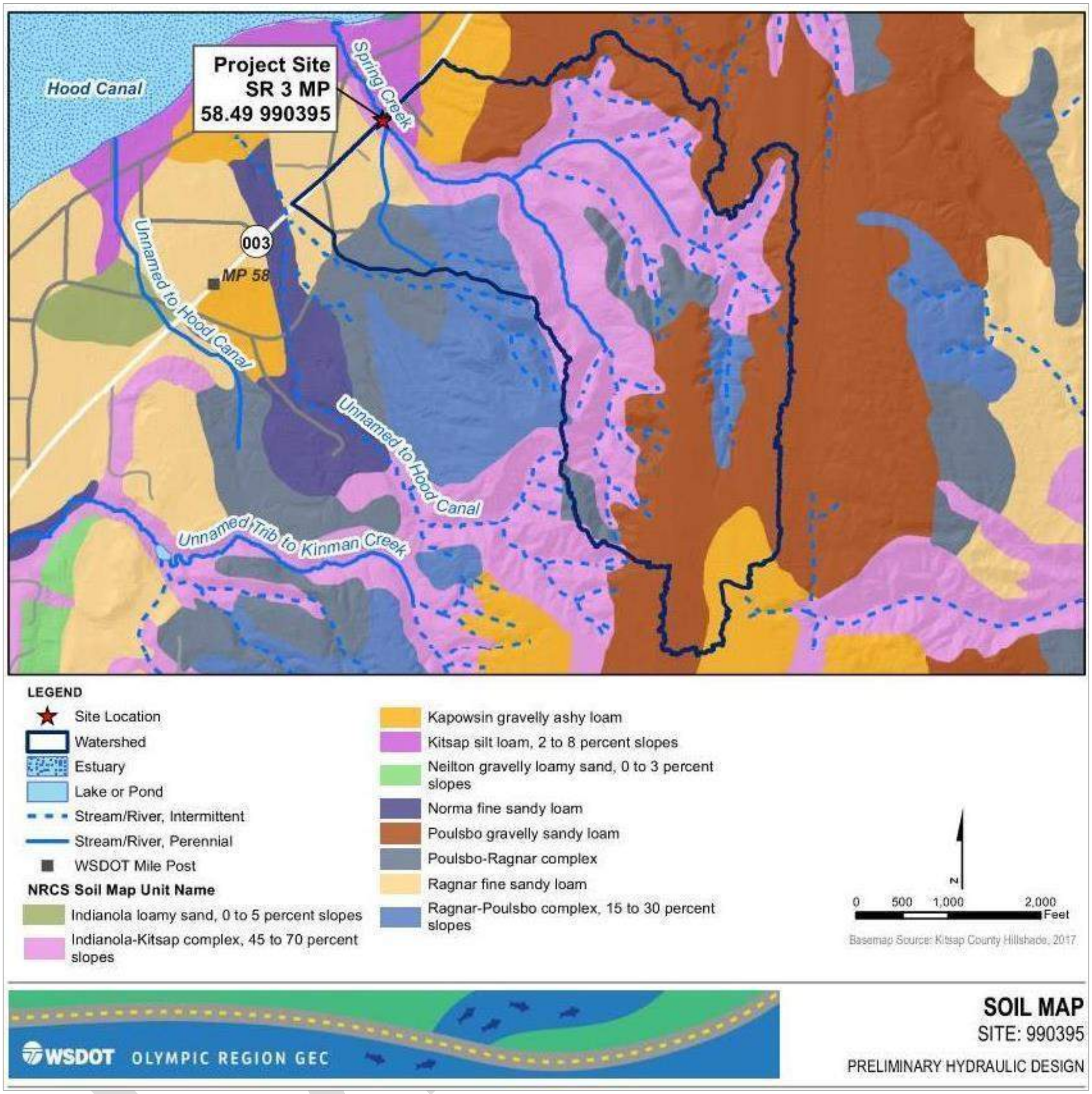

Figure 7: Soils map

2.4 Fish Presence in the Project Area

Jacobs staff reviewed multiple publicly available information sources regarding historic and current fisheries resources and distribution within the project area, including the following:

- National Marine Fisheries Service (NMFS) Endangered Species Act (ESA) Critical Habitat Mapper (n.d.-a)
- NMFS Essential Fish Habitat Mapper (n.d.-b)
- Statewide Washington Integrated Fish Distribution (SWIFD) database (Northwest Indian Fisheries Commission n.d.)
- USGS National Hydrography Dataset (2019)
- Washington State Department of Ecology (Ecology) Watershed Restoration and Enhancement Draft Plan, WRIA 15 Kitsap Watershed (2021)
- Washington State Recreation and Conservation Office project database search by WRIA (Ecology n.d.; No projects within the vicinity)
- WDFW Fish Passage and Diversion Screening Inventory (n.d.-b), which includes a compilation of barrier and habitat assessment reports
- WDFW Fish Passage and Diversion Screening Inventory Database, Level A Culvert Assessment Report for Spring Creek (2000)
- WDFW Hydraulic Project Approval database search by Section/Township/Range (n.d.-c; No active HPA applications)
- Site observations by a Jacobs biologist on November 30, 2021

Jacobs representatives, including a fisheries biologist, conducted Site Visit 2 on November 30, 2021, to document the existing conditions of the channel upstream and downstream of the crossing. The National Hydrography Dataset (USGS 2019) documents Spring Creek as a perennially flowing stream. Field indications support the determination of a perennially flowing waterbody, including a well-defined channel, clean sand and gravel substrate, and lack of vegetation below ordinary high water.

Spring Creek has the potential to support migration, spawning, and rearing of native resident and anadromous fish species both upstream and downstream of the existing crossing, including species listed in Table 2. Streams with a channel width greater than 2 feet and a contributing basin larger than 50 acres in Western Washington are presumed to have fish use (WAC 22-16-131). Streams with existing or historic fish use within this region are mapped as Essential Fish Habitat for Pacific salmon under the Magnuson-Stevens Fishery Conservation and Management Act, therefore, Spring Creek is identified as Essential Fish Habitat for Pacific salmon under the Act. Spring Creek is not listed as designated critical habitat for aquatic species under the federal ESA. Section 2.6.3 discusses fish habitat quality including fish utilization by life stages in greater detail.

Table 2 summarizes aquatic species that are documented to occur within the project area based on this data review.

Table 2: Native fish species potentially present within the project area

Species	Presence (presumed, modeled, or documented)	Data source	ESA listing
Puget Sound Steelhead (*O. mykiss)*	Modeled - Gradient Accessible	SWIFD Web App	Threatened, NMFS
	Potential	WDFW Fish Passage Report	
Coho Salmon (*O. kisutch*)	Modeled - Gradient Accessible	SWIFD Web App	Not Listed
	Potential	WDFW Fish Passage Report	
Cutthroat Trout (Sea Run) (*O. clarkii clarkia*)	Modeled - Gradient Accessible	SWIFD Web App	Not Listed
	Potential	WDFW Fish Passage Report	
Cutthroat Trout (Resident) (*O. clarkii clarkia*)	Modeled - Gradient Accessible	SWIFD Web App	Not Listed
	Potential	WDFW Fish Passage Report	

Sources: Northwest Indian Fisheries Commission n.d.; WDFW 2000.

2.5 Wildlife Connectivity

The 1-mile-long segment that Spring Creek falls in is not ranked for Ecological Stewardship and low priority for Wildlife-related Safety by WSDOT HQ ESO. Adjacent segments to the north are not ranked and to the south are ranked low. A wildlife connectivity memorandum will not be provided at this site and additional width or height has not been recommended by WSDOT HQ ESO for wildlife connectivity purposes.

2.6 Site Assessment

2.6.1 Data Collection

On November 30, 2021, Jacobs staff investigated approximately 200 feet upstream of the culvert inlet and 200 feet downstream of the culvert outlet. Jacobs performed four pebble counts (PC 1 through PC 4), two upstream and two downstream. Jacobs also measured six bankfull widths (BFW) (US 1 through US 3, and DS 1 [labeled as DS 20], DS 2 [labeled as DS 22], and DS 3 [labeled as DS 24]), three upstream and three downstream.

Hydraulic survey was subsequently received on January 11, 2022. Survey extends roughly 230 feet upstream of the existing culvert inlet and roughly 260 feet downstream of the existing culvert outlet. The width of survey along the stream is roughly 170 feet at the ends of the existing culvert and tapers to roughly 50 feet at the upstream and downstream extents of the survey. SR 3 is surveyed greater than 200 feet both north and south of the existing crossing.

The reference reach and BFW concurrence site visit (Site Visit 3) with WDFW and the Tribes occurred on February 15, 2022. Three additional BFW measurements (DS 21, DS 23, and DS 25) were taken. No additional pebble counts were collected. The group agreed that it was reasonable to have a BFW of 7.5 feet for the proposed channel geometry based on the reference reach, discussed in further detail in Section 2.7.1.

Figure 8 shows the locations of all BFW measurements, pebble counts, and the reference reach location. Section 2.7.2 provides further detail on BFW measurements, and Section 2.7.3 provides further detail on sediment. Appendix B contains the Site Visit 2 field report.

Figure 8: Reference reach, bankfull width, and pebble count locations

2.6.2 Existing Conditions

The existing crossing consists of a 36-inch-diameter, 119-foot-long, precast concrete pipe that runs east to west at a skew to the highway, with an overall gradient of 4.0 percent. There is approximately 20 to 30 vertical feet between the culvert crown and the road surface. The other infrastructure noted in the vicinity of the crossing is Scenic Drive NE (WDFW ID 993196 and is not considered a fish barrier) which runs perpendicular to Spring Creek located approximately 400 feet downstream of the project crossing. As-builts of SR 3 were obtained from WSDOT HQ and did not show any relevant information regarding the existing 36-inch-diameter crossing. WSDOT maintenance did not indicate any recent maintenance activity, and field observations did not reveal any obvious signs of maintenance.

Due to the surrounding valley walls and steep channel gradient (>3 percent), sinuosity upstream of the crossing is limited within the survey extent shown in the plan sheets (Appendix D), and bends are commonly caused by obstructions, such as woody debris. Despite the steep channel gradient, a well-developed floodplain was observed due to backwatering at the culvert inlet. At the culvert inlet there is one meander bend with a radius of curvature of approximately 15 feet. The upstream channel within the survey extent has a moderately steep gradient (3.8 percent) and wetland-like reach with low, indistinct banks; few streamside conifers; and relatively wide and shallow geometry (Figure 9). Backwater conditions at the crossing inlet appear to drive a poorly defined bankline and a wide, shallow channel shape. This channel shape, with a featureless bed, is characteristic of a plane bed channel type. No obvious excess deposition was observed but the geometry, bank height, and floodplain connection indicate that deposition is occurring.

Just upstream of the culvert inlet, UNT to Spring Creek joins Spring Creek. During Site Visits 2 and 3, observations and measurements were not performed on this UNT. It is assumed that this a small tributary, overgrown and not readily observable. Topographic surveying did not identify the tributary. However, desktop analysis displayed this tributary and the design team accounted for its drainage basin (approximately 44 acres) in the hydrologic analysis.

Downstream of the 119-foot crossing, the channel emerges from the outlet down a short, steep riprap embankment up to the roadway. Valley confinement downstream is similar to that observed upstream. The overall channel gradient (within the limits of the survey) is steeper (4.9 percent). These factors drive limited sinuosity, though, like upstream, meander bends are observed as a result of interaction with flow obstructions.

Farther downstream (approximately 150 feet downstream of the culvert outlet), the channel includes undercut banks and a mix of legacy coniferous LWM in various stages of decay and newer deciduous LWM that has formed some pool sections (Figure 10). The steps noted downstream and in the reference reach are comprised of legacy LWM and racked debris. These steps have naturally evolved and degraded over time to create nuanced and complex steps that are varying heights, from 0.5 to 1.8 feet. The undercut banks are primarily caused from localized erosion and likely historic tree falls exposing significant portions of soil in the vicinity of the root system. The term “legacy” LWM refers to LWM present in streams prior to widespread logging in the early twentieth century and may appear in advanced stages of decay. It is likely that the historic logging created some of the LWM steps noted throughout the reach, but this is speculative. The longitudinal slope of the channel varies from 3 to 6.4 percent in the downstream reach. With the exception of the vegetation clearing performed to facilitate the site survey, no obvious signs of maintenance were noted. Section 2.6.4 provides information on existing riparian vegetation conditions, LWM, and canopy cover.

The conditions described in this section apply roughly to the survey extents shown in Appendix D, both upstream and downstream. These extents were observed during Site Visits 2 and 3, and the following photographs show exiting conditions throughout the observed reaches. Figure 9, Figure 10, Figure 11, and Figure 12 show examples of existing conditions observed.

The culvert crossing is a full barrier to fish passage due to slope. The steep slope at that length and the lack of habitat within the structure does not allow any point of rest for any fish. Additional information on fish habitat character and quality is in Section 2.6.3.

Figure 9: Upstream reach, living tree roots create channel complexity and pockets of slower water, providing foraging opportunities for juvenile fish (approximately 220 feet upstream of culvert inlet).

Figure 10: Downstream reach, legacy LWM, and felled LWM (approximately 30 feet downstream of culvert outlet).

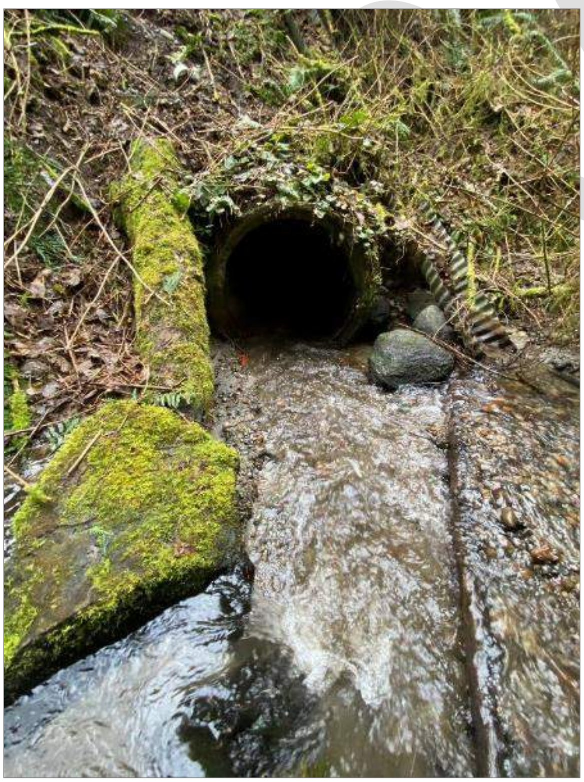

Figure 11: Upstream culvert inlet

Figure 12: Downstream culvert outlet

2.6.3 Fish Habitat Character and Quality

Instream habitat conditions in the upstream reach of Spring Creek consist of a riffle-run morphology. The floodplain within this reach averages more than twice the width of ordinary high water and consists of low-lying vegetated floodplain benches, allowing for floodplain connectivity during bank-topping flows. Pools are relatively infrequent, consisting primarily of plunge pools created by legacy coniferous LWM and living riparian tree roots. Pool depths ranged from approximately 6 to 12 inches and consisted of forced steps but few lateral pools.

Floodplain wetlands were observed, though wetland vegetation occurs in a narrow band in the lowest lying wetlands associated with the stream. The substrate consists primarily of fine to coarse sand and small- to medium-sized gravels with infrequent cobble. The size of the stream, substrate, and water depth is suitable for rearing, migration, and spawning of anadromous and resident salmonids. Suitable spawning and rearing habitat for all resident and anadromous juvenile fish is present throughout the upstream reach, particularly where LWM has engaged with the low-flow channel, creating channel complexity for all life stages, including habitat for refugia, and foraging as well as subsurface flow critical for redd incubation.

Instream habitat conditions in the downstream reach consist of a run or glide with intermittent step-pool morphology within a moderately confined valley floor. Pools are infrequent and are limited to legacy LWM and more recent deciduous material. The channel appears to be slightly downcut in this reach, limiting floodplain connectivity. Some recent downed LWM spans the channel but is not actively engaged with the low-flow channel. Instream substrate consists of fine to coarse sand and small- to medium-sized gravels with few cobbles observed. Several small, abrupt grade changes within the channel are created by small legacy LWM remnants, and living tree roots function as a grade control, creating plunge pools that serve as refugia for juvenile salmonids (Figure 9 and Figure 13).

Figure 13: Downstream reach, step-pool and grade control created by buried legacy LWM and living tree roots (approximately 150 downstream of culvert outlet).

2.6.4 Riparian Conditions, Large Wood, and Other Habitat Features

Riparian vegetation within the upstream and downstream reaches consist predominantly of mature, closed-canopy, coniferous-deciduous forested stands greater than 150 feet or more on both sides of the stream (Figure 14). Approximately 0.5-mile upstream of SR 3, the stream flows through Port Gamble Forest Heritage Park (Kitsap County), where the riparian width is over 500 feet on either side of the stream, likely contributing to cooler summer water temperatures in downstream reaches.

The Spring Creek overstory is dominated by mature mid- to late-successional coniferous and deciduous riparian community species, mostly Western red cedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), Western hemlock (*Tsuga heterophylla*), big-leaf maple (*Acer macrophyllum*), and Western red alder (*Alnus rubra*). Understory species predominantly consist of native species, including salmonberry (*Rubus spectabilis*), sword fern (*Polystichum munitum*), piggyback plant (*Tolmiea menziesii*), and other native forb species. Western red alder snags were noted in the upstream reach, allowing for sun to reach the canopy floor and a slightly denser shrub understory than was observed in the downstream reach. Riparian conditions in the downstream reach had notably more closed canopies, with an open understory and a less dense understory of shrubs than was observed in the upstream reach. The Jacobs biologist observed ivy (*Hedera helix*) in the canopy within the downstream reach, closer to rural residential houses.

The majority of instream coniferous LWM in the upstream and downstream reaches is relatively small coniferous material, compared to its potential size for the region, and in an advanced decaying state (legacy LWM). The removal of most mature conifers across the West eliminated a generation of coniferous LWM recruitment potential. Mature trees within the upstream and downstream reaches likely regenerated within the last 100 years and are of similar age, consistent with early twentieth-century, postindustrial logging regrowth. The expectant life span of these coniferous tree species can exceed several hundred years; therefore, outside of environmental disturbance such as windfall, these stands would not be expected to serve as significant LWM recruitment potential due to their relative natural longevity. Environmental disturbance, such as periodic windfall and disease, would be the more likely pathways for more significant LWM recruitment than age-induced decay.

Deciduous LWM is also present, though in smaller quantities. Deciduous wood plays an important role providing instream nutrient recruitment but has a much faster decay rate compared to coniferous LWM, limiting its role in forming longer-term channel complexity, including pool formation. The presence of LWM and corresponding pools for salmonid refugia and cover in both reaches is moderately deficient as compared to the target number of key pieces of LWM for Western Washington (WSDOT 2022b; Fox and Bolton 2007). No evidence of beaver activity was noted. Other instream habitat features are discussed in Section 2.6.3.

Figure 14: Riparian conditions in the upstream reach, noting presence of snags and a shrub-dominated understory.

2.7 Geomorphology

Geomorphic information provided for this site includes selection of a reference reach, the geometry and cross sections of the channel, and stability of the channel both vertically and laterally of Spring Creek.

2.7.1 Reference Reach Selection

To inform new channel design, the reference reach was identified during Site Visit 2 and confirmed at the concurrence site visit on February 15, 2022. The identified reference reach is located in the downstream channel segment, starting approximately 100 feet downstream of the culvert outlet and extending 100 feet downstream to the end of the field reconnaissance. This reach was selected because it is near the existing crossing, has a similar slope to the anticipated crossing, and appears to have been largely undisturbed since it was logged in the early twentieth century, with a mature forest of mixed cedar and fir and an understory of ferns (Figure 15). This reach is also not influenced by deposition, unlike the upstream reaches.

The reference reach primarily consists of longer (5 to 10 feet) riffles or runs separated by small woody material (SWM)-facilitated steps wedged between legacy LWM and/or vegetated banks that create pools. The banks are well vegetated and cohesive. Similar to both upstream and downstream reaches, the channel in the reference reach is mildly incised, but active incision was not observed and exhibits vertical stability.

Accumulated fallen leaves on the former floodplain indicate that winter high flows did not and likely rarely, if ever, engage the disconnected floodplain. However, an inset floodplain is developing and gravel bars have formed along the channel margins, indicating the concurred BFW may be appropriate or slightly oversized for channel-forming processes. The selected reference reach also includes an atypically large, wood-forced step approximately 1.8 feet high and 5 feet long. While this step was likely created through natural processes, its dimensions are omitted from further consideration in design.

BFW measurements (DS 23 and DS 24) were collected in the reference reach (presented in Section 2.7.2) during Site Visit 2 and Site Visit 3 (the concurrence site visit), respectively. The location of the reference reach, BFW measurements, and pebble counts are shown on Figure 8.

The upstream adjacent channel segment is similar to the downstream segment, but with slightly more variation in BFW and a slightly higher gradient (5.2 percent versus 3.7 percent in the downstream segment). Ultimately, the downstream segment was considered a better reference reach because the channel bedforms and spacing provided a better analog.

Figure 15: Reference reach, looking upstream

2.7.2 Channel Geometry

BFW was measured at six locations during the November 30, 2021, site visit with three upstream (US 1 through US 3; Figure 17) and three downstream (DS 20, DS 22, and DS 24; Figure 18) including two in the reference reach. BFW measurements varied from 6.0 to 9.4 feet, with an average of 6.5. During the concurrence site visit on February 15, 2022, three more BFW measurements (DS 21, DS 23, and DS 25) were made in the downstream reach by WDFW and tribal representatives, which ranged from 6.5 to 11 feet. The average of the combined reference reach BFW measurements from the two site visits is 7.4 feet, and the average is 7.7 feet (Table 3). In this case, the average value of BFW is not commonly observed in the field. Cross sections influenced by LWM tend to be wider, and cross sections without LWM tend to be much narrower.

It was agreed at the concurrence meeting with WDFW and the Tribes that for channel design purposes, a BFW of 7.5 feet is appropriate to help maintain adequate flow depth at lower flows, maintain sediment transport continuity, and reduce the risk of developing a plane-bed morphology in the crossing. However, the BFW of the design channel was adjusted to 5.5 feet to ensure that, as the channel widens over time (due to the influence of wood and wood analogs), the channel is not over widened and shallow compared to the average BFW. The resulting channel reach will be a mosaic of channel widths, some narrower, some wider, that represent the range of observed channel widths. The group also agreed that the crossing structure be designed to accommodate channel widths of 11 to 12 feet that were observed upstream of some of the steps in the reference reach.

The bank heights range from 1 to 2 feet downstream of the crossing, and are comprised primarily of decaying organic material, live ferns, sediment, and cobble. The left bank heights were more clearly defined than the right bank heights. Because the channel is incised, the bank heights do not coincide with the bankfull depth. The bankfull depth in the reference reach was determined to be roughly 0.9 foot on Site Visit 2. With a concurred BFW of 7.5 feet, this yields a width-to-depth ratio of 8.3. Based on the Stream Evolution Model presented in Cluer and Thorne (2013) on Figure 16, Spring Creek is in Stage 5 of the stream channel evolution. The channel has incised into the valley surface but many reaches are now constructing an inset floodplain. Channel floodplain widths vary from 5 to 10 feet but are rarely accessed due to the confined nature of the channel. Floodplain slopes range from approximately 2 to 15 percent. The disconnected nature of the floodplain leads to channel instability and loss of aquatic habitat.

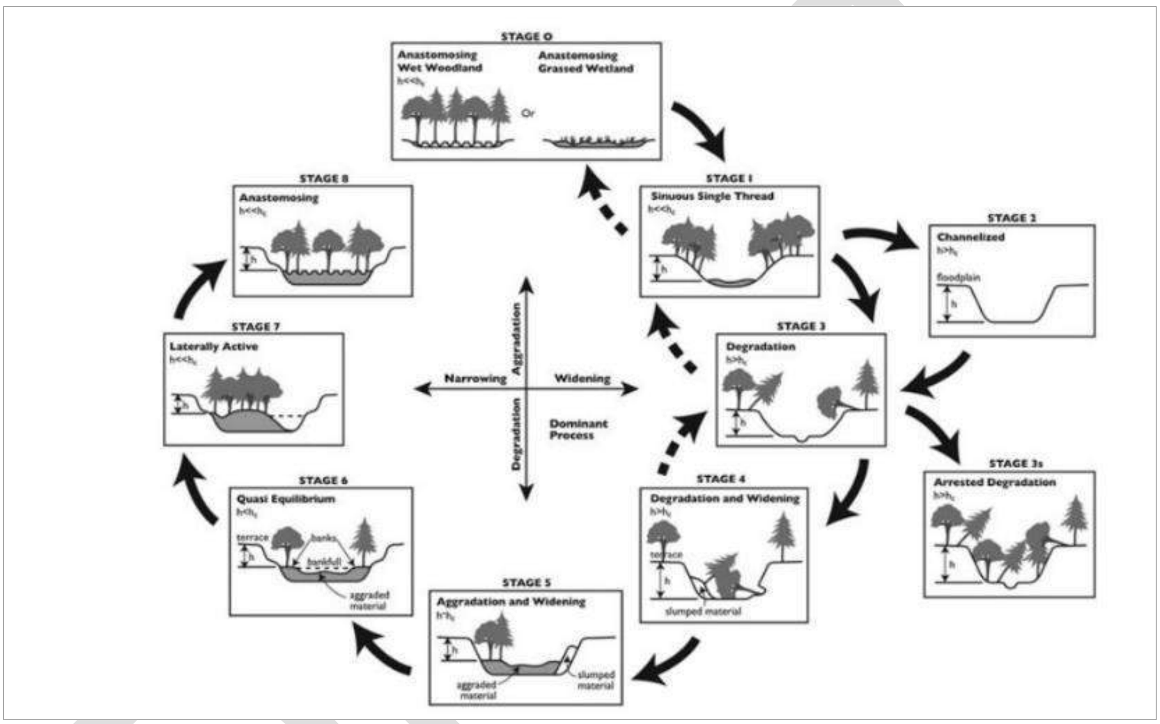

Figure 16: Stream evolution model (Cluer and Thorne 2013)

The channel is located in a partially confined valley. The upstream reach has a moderate gradient of 2 to 5 percent (3.8 percent overall average). Generally, the channel follows a trapezoidal shape and is relatively wide and shallow. The upstream reach has a sinuosity of approximately 1.2, mildly more sinuous than the downstream each. At the crossing inlet, backwater conditions and likely deposition create a poorly defined bankline and a wide, shallow channel shape. Downstream of the crossing, the valley is partially confined and the reference reach has a sinuosity of 1.1. The downstream reach gradient ranges from 3 to 6.4 percent.

The slope of the reference reach is 3.7 percent, which is comparable to the proposed slope of the crossing. The channel through the reference reach exhibits a run or glide morphology, punctuated by periodic steps formed from legacy LWM or boulders, which likely originated in the glacial till near where they are currently situated (i.e., lag deposits). Church and Zimmerman (2007) describe this as a type of step-pool channel, specifically a “step-pool unit with a tread” (Figure 19). Steps vary in height from a few inches to approximately 2 feet (Figure 13).

Figure 17: US BFW 2 measurement

Figure 18: DS BFW 22 measurement

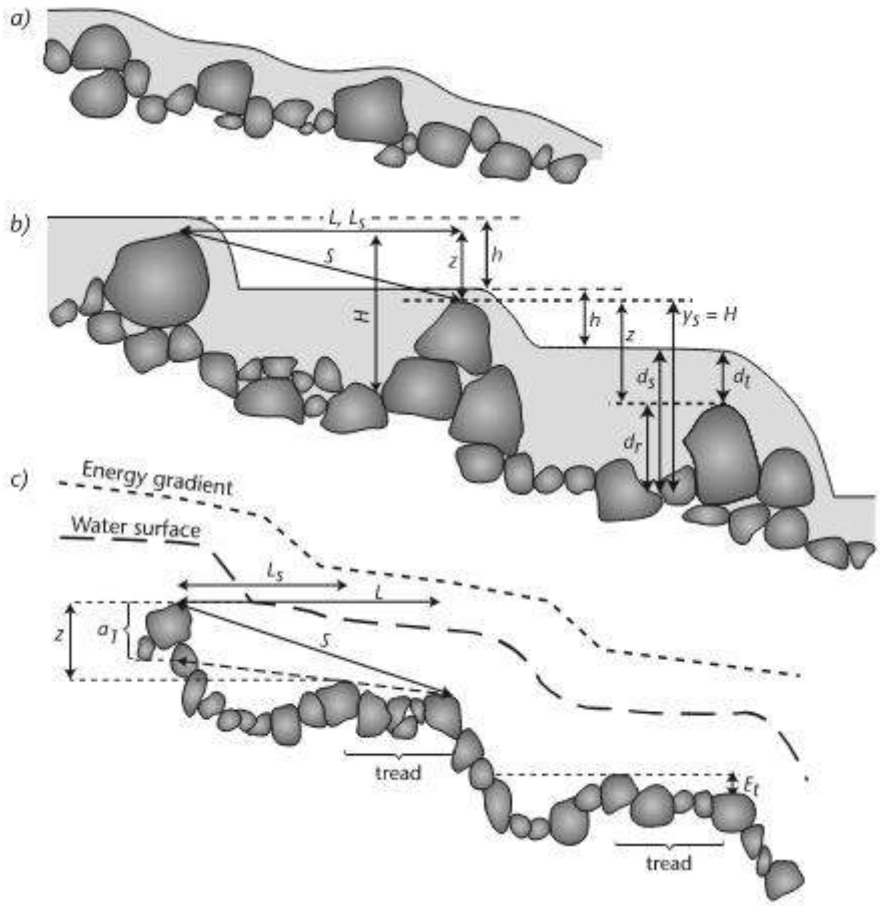

Figure 2. Illustrations with definitions of (a) rapid channel morphology, (b) a step-pool unit with no tread between successive pools (definitions given in the downstream pool are used particularly in studies of pool scour), and (c) a step-pool unit with a tread, extended forms of which may be considered equivalent to a run.

Figure 19: Step-pool types - Profile c describes the reference reach, with "treads" that are equivalent to runs (Church and Zimmerman 2007)

Upstream of each step are lower-gradient run and glide channel types, often with an asymmetrical cross section (i.e., the thalweg on one side of the channel and a bar formed on the opposite side) (Figure 21).These portions of the channel are typically wide and somewhat shallow. Downstream of each step are deep pools and a more incised channel with steep, high banks that likely prevent flows from accessing the floodplain at all but exceptional flows. Accumulated leaf litter indicates relatively infrequent floodplain activation.

LWM is not abundant in this reach but is geomorphically functional where it does exist, forming steps and adding channel complexity (Figure 20). The forested riparian area provides opportunities for LWM recruitment, but with most of the trees being long-lived coniferous species, recruitment is somewhat limited.

Figure 20: Step in the downstream reach formed from LWM and a boulder; the drop is approximately 1.8 feet.

Table 3: Bankfull width measurements

BFW number	Width (feet)	Included in design average?	Location measured (distance from culvert inlet (US) and outlet (DS))	Concurrence notes
US 1	5	N	14 feet upstream	Comanagers concurred on 02/15/2022
US 2	7.5	N	80 feet upstream	—
US 3	9.4	N	180 feet upstream	—
DS 20	6.5	Y	30 feet downstream	Measured by comanagers 2/15/2022
DS 21[a]	7.4	Y	70 feet downstream	Measured by comanagers 2/15/2022
DS 22	7.5	Y	100 feet downstream	Measured by comanagers 2/15/2022
DS 23[a]	8.5	Y	130 feet downstream	Measured by comanagers 2/15/2022
DS 24 [a]	8.5	Y	180 feet downstream	Comanagers concurred on 02/15/2022
DS 25	11	N	240 feet downstream	Measured by comanagers 2/15/2022
Design average	7.7 (Agreed to 7.5)	—	—	Agreed to 7.5 per field discussions with comanagers

a. BFW location measurements are approximate and inferred from best available data collected in the field.

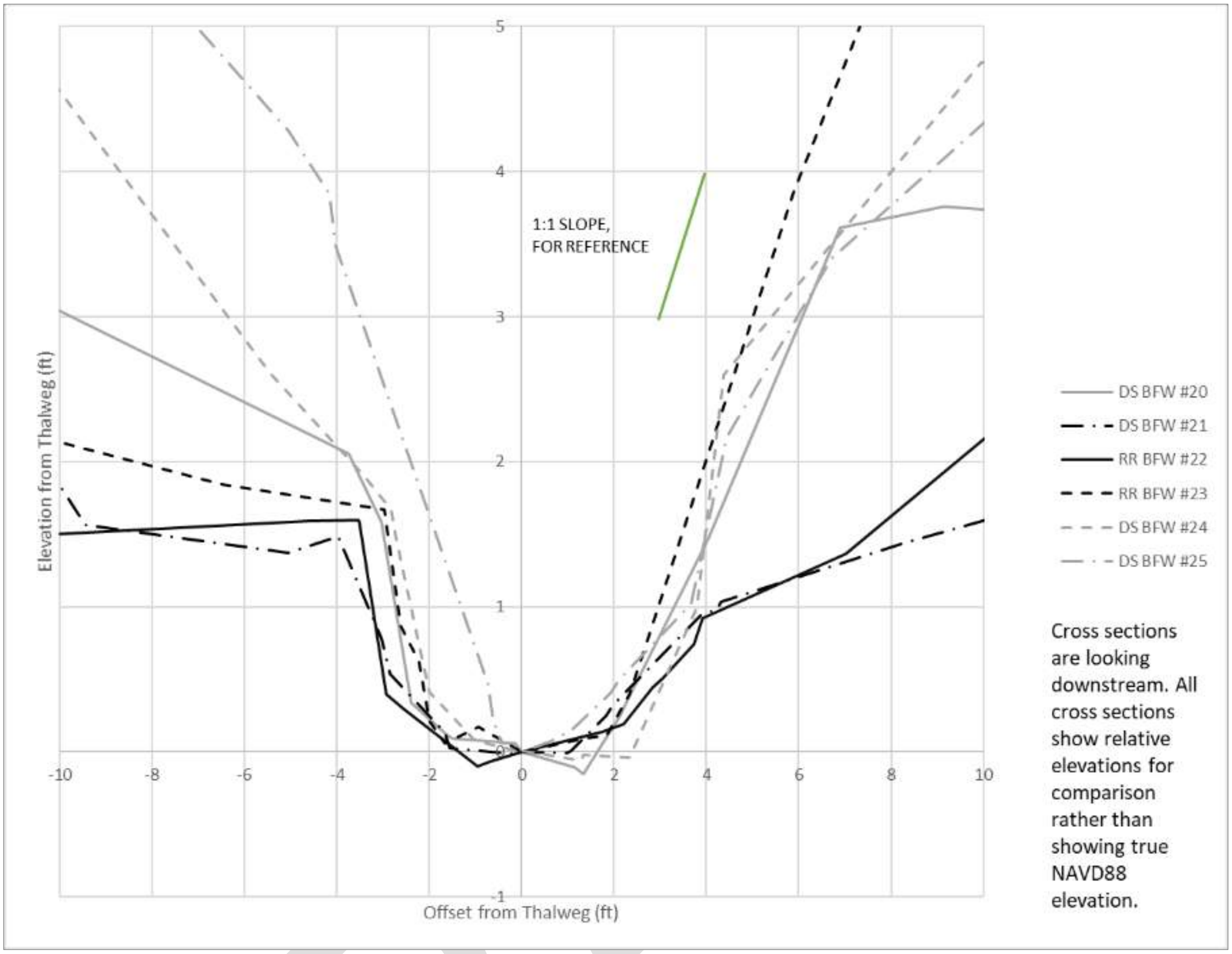

Figure 21: Existing cross section examples

2.7.2.1 Floodplain Utilization Ratio

The FUR is defined as the flood-prone width (FPW) divided by the BFW. For the purpose of calculating the FUR for Spring Creek, the FPW was assumed to be the water surface width at the 100-year flood from the existing-conditions model with backwater impacts removed; the BFW used was the agreed upon concurred BFW of 7.5 feet. The existing-conditions hydraulic model was produced in the Bureau of Reclamation's Sedimentation and River Hydraulics – Two Dimension (SRH-2D) Version 3.3.1 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (2020). To remove the backwater impacts at the SR 3 crossing during the 100-year flood, the diameter of the existing culvert was artificially increased from 3 feet to 12 feet using the HY-8 Culvert Analysis Program (HY-8; Federal Highway Administration 2022). All other model input parameters were consistent with the existing-conditions model described in Section 5. This model simulation does not meet the requirements of a natural conditions model.

FPWs were measured at three locations in the upstream reach and four locations in the downstream reach (three of which are in the reference reach). Figure 22 shows the cross section locations where FPWs were measured, and Table 4 summarizes the FPW, FUR, and nature of confinement for each cross section. Generally, a FUR under 3.0 is considered a confined channel, and a FUR above 3.0 is considered an unconfined channel.

FUR values at the project site vary between 1.1 and 4.4. Upstream of the existing crossing, the highest calculated FUR was 4.4 and the lowest was 1.6, with an average of 2.6 in the upstream reach. Downstream of the crossing, the highest FUR calculated was 2.4 and the lowest calculated was 1.1, with an average of 1.5 in the downstream reach. These values indicate the channel was confined both upstream and downstream of the existing crossing, more so in the downstream reach. The average for the upstream and downstream reaches combined were 14.6 feet for the FPW, resulting in an average FUR of 2.0. These FUR values are generally consistent with the upstream and downstream channel geometry observations described in Section 2.7.2.

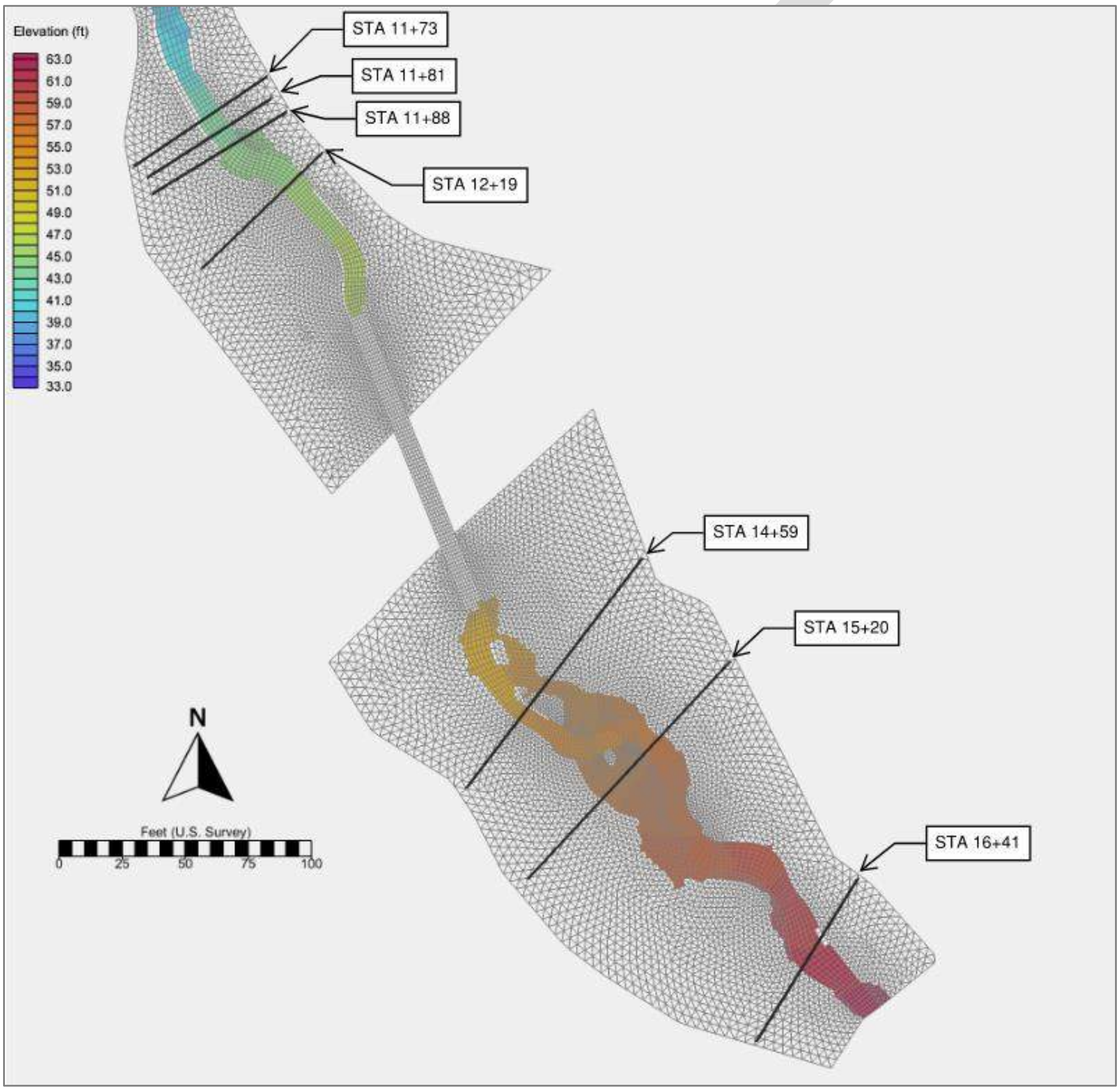

Figure 22: FUR Locations

Table 4: FUR determination

Station	FPW (ft)	FUR	Confined/unconfined	Included in average FUR determination
US 3 16+41	13.7	1.5	Confined	Yes
US 2 15+20	33.2	4.4	Unconfined	Yes
US 1 14+59	11.8	2.4	Confined	Yes
DS 20 12+19	9.2	1.2	Confined	Yes
DS 22 11+88	18.1	2.4	Confined	Yes
DS 23 11+81 (reference reach)	8.2	1.0	Confined	Yes
DS 24 11+73 (reference reach)	8.0	1.0	Confined	Yes
Average	**14.6**	**2.0**	**Confined**	**N/A**

2.7.3 Sediment

Upstream and downstream of the crossing, the bed material is typically clast-supported, meaning larger clasts are touching and supporting each other. Interstices between the clasts contain sand and organic debris (Figure 23). The channel bed material upstream and downstream of the crossing was characterized by a Wolman pebble count both upstream and downstream. Four pebble counts were conducted, two in the upstream reach and two in the downstream reach (one within the reference reach) (Figure 8). Overall, the results at all locations were similar, displaying a bimodal distribution with peaks in the sand-sized particles and another in the 0.5- to 1.5-inch range. D_{50} ranged from 0.4 to 0.5 inches, and D_{84} from 0.9 to 1.2 inches. D_{50} and D_{84} are the particle sizes where 50 percent and 84 percent, respectively, of the sediment diameters in the sample size are smaller.

As noted in Section 2.3, the watershed material (glacial drift) and upstream landslide debris create abundant sediment sources that fine the bed material in spite of the transport capacity of the channel. These fine sediments are likely mobilized at flood conditions but high incoming load replaces fine sediments on the falling limb of the flood event.

Boulders were noted in the stream but were not specifically included in the pebble counts as they are not part of the load transported by the stream. Rather, they are likely exhumed, glacial features. The approximate size of boulders ranged from 1- to 2-man (12 to 24 inches in diameter). The average median grain size (D_{50}) is 0.5 inch (Table 5). Sediment size distribution for all pebble counts are shown on Figure 24 and Figure 25 for the upstream and downstream reaches, respectively.

Table 5: Sediment properties near the project crossing

Particle size	US Pebble Count 1 diameter (in)	US Pebble Count 2 diameter (in)	DS Pebble Count 3 diameter (in)	DS Pebble Count 4 diameter (in)	Average diameter for design (in)
Included in average?	Yes	Yes	Yes	Yes	N/A
$\mathbf{D_{16}}$	0.08	0.08	0.05	0.02	0.06
$\mathbf{D_{50}}$	0.4	0.5	0.4	0.5	0.5
$\mathbf{D_{84}}$	1.1	1.2	0.9	1.1	1.1
$\mathbf{D_{95}}$	1.7	1.7	1.3	1.7	1.6
$\mathbf{D_{100}}$	3.6	2.5	3.6	5.0	3.7

DS = downstream
US = upstream

Figure 23: Typical sediment size distribution, located within the reference reach downstream of the crossing

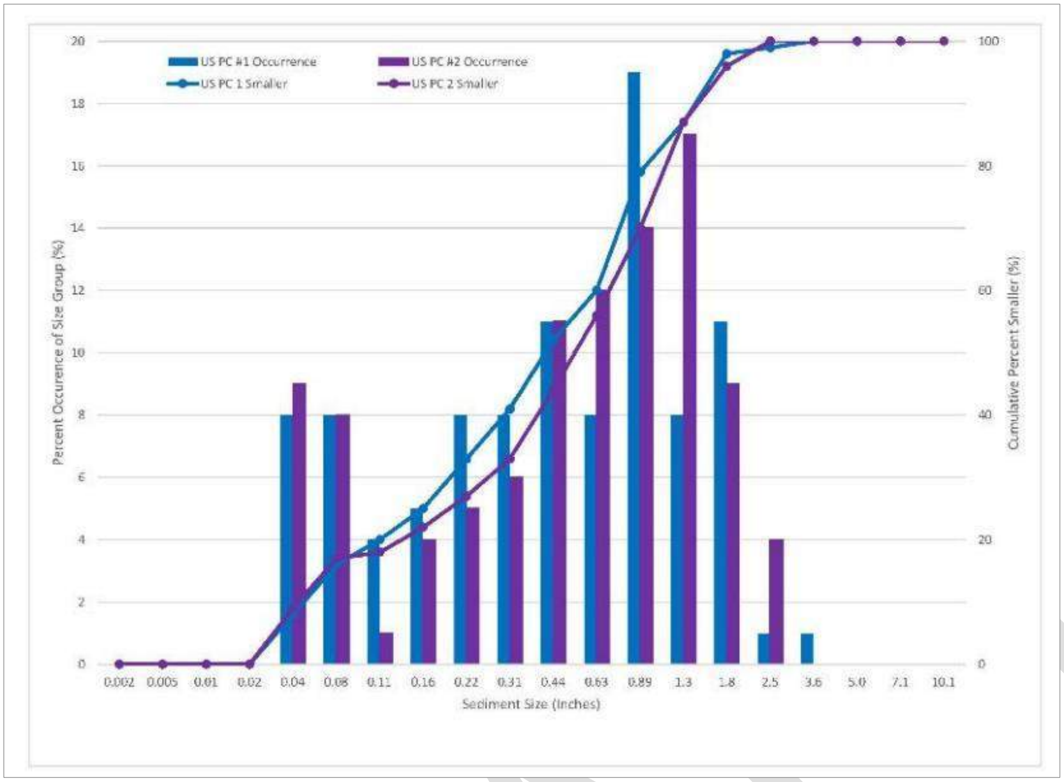

Figure 24: Upstream reach sediment size distribution

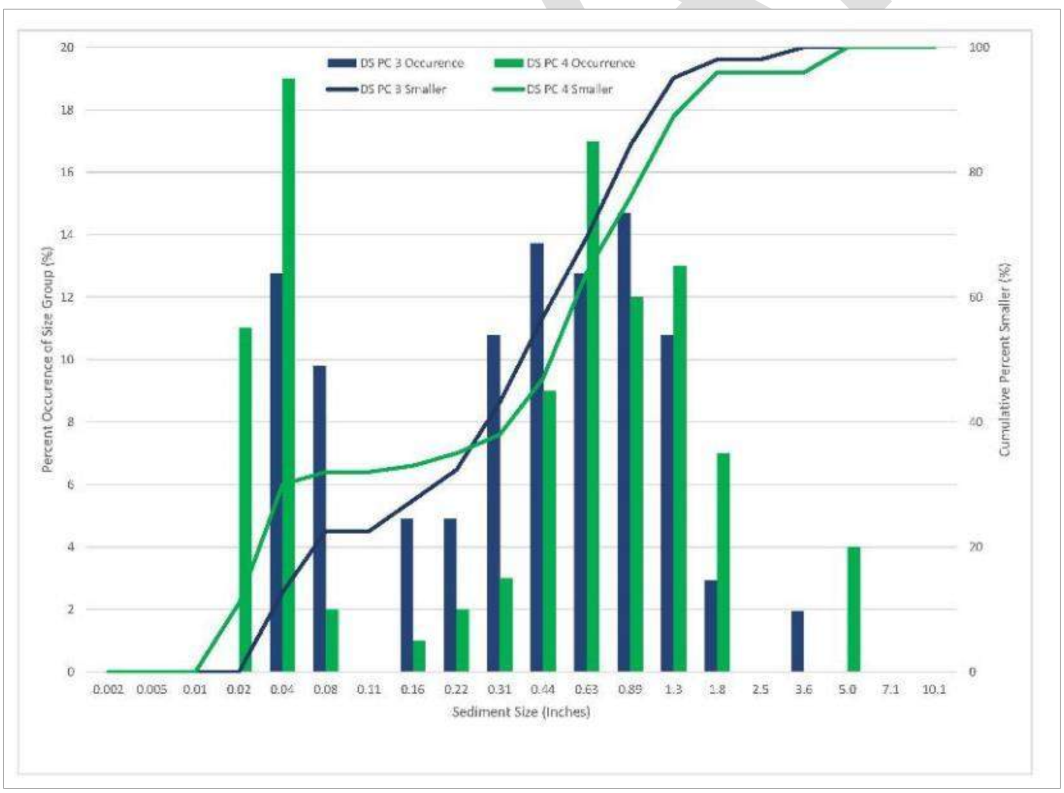

Figure 25: Downstream reach sediment size distribution

2.7.4 Vertical Channel Stability

Spring Creek has a healthy supply of sediment derived from the glacial deposits that make up the basin and the potential landslides upstream of the crossing (see Section 2.3). The longitudinal profile, shown on Figure 26 was created using 2018 Kitsap County LiDAR and 2021 WSDOT topographic survey data. The profile indicates that the gradient upstream and downstream of the crossing is consistent at 4 percent, which approximates a visually estimated equilibrium slope through the crossing and suggests that the stream is not adjusting to any major changes or inbalances in inputs.

Even though the profile is generally straight with a consistent slope, at finer spatial scales, it exhibits steps. The steps in the profile enable lower-gradient channel types, such as glides, to persist by slowing flow behind small accumulations of wood that function as steps. These steps function as minor grade control structures. Longevity of these steps is relatively short, but there are sufficient steps to hold the overall grade and likely sufficient recruitment of woody material to reform steps. Approximately 125 feet downstream of the crossing is a roughly 1.8-foot-high step (see Appendix D)—held by a combination of roots, small wood, and boulders—which should be considered a deformable feature. If that step degrades, it could initiate a headcut, regrading the channel upstream through the crossing. With an equilbrium slope of roughly 4 percent, this would produce less than a foot of degradation at the crossing outlet. See Section 7.2 for more discussion of degradation potential.

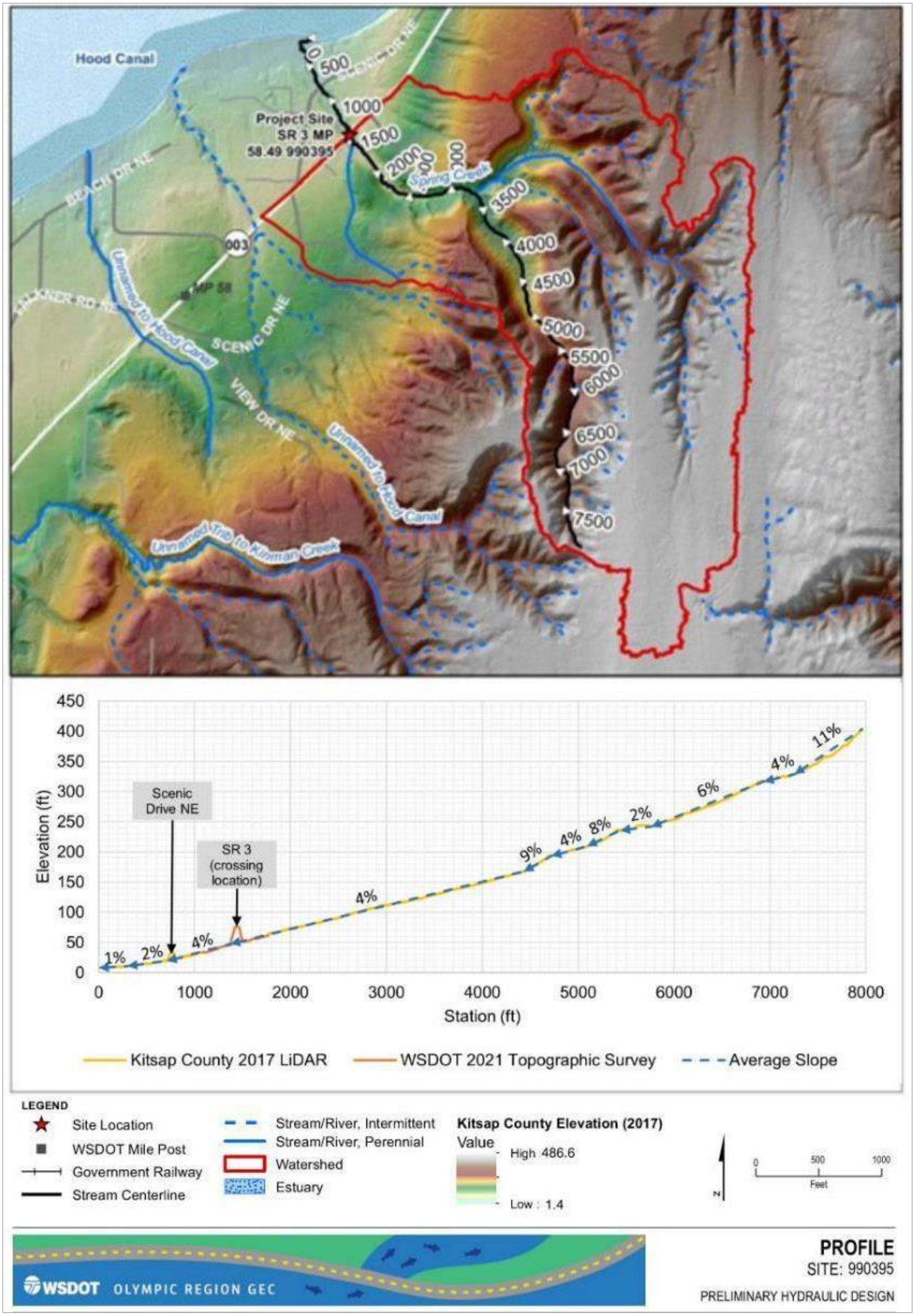

Figure 26: Watershed-scale longitudinal profile

2.7.5 Channel Migration

The channel has a generally low sinuosity of less than 1.1. Overall bank stability is good, with only small, isolated areas of bank erosion, typically associated with downcutting at steps but not related to channel migration. Mild incision limits floodplain connectivity, though inset floodplain development was commonly observed. No floodplain channels were noted in the field or observed on the LiDAR survey.

The channel morphology tends toward a step-pool configuration (though with a notable tread after each pool), which are not typically characterized by high sinuosity and channel migration. These geomorphic conditions point to a medium risk of geomorphic channel migration. However, two factors create a moderate risk of channel migration: (1) a relatively high sediment load and a channel-spanning blockage could accumulate sediment and force the channel to migrate around it, and (2) geotechnical data indicates relatively erodible materials that would have low resistance to channel migration (WSDOT 2022c). These factors are attenuated by resistance to incision by extensive mature vegetation in the floodplain.

3 Hydrology and Peak Flow Estimates

This section describes the Spring Creek watershed delineation, the methods utilized for peak flow estimation and validation, and projected climate change impacts to peak flows. Low summer flow conditions are not known and were not evaluated as it is beyond the scope of this PHD. Low-flow calculations should be considered to support step height design as part of the final hydraulic design (FHD).

There is no historical flow data available for Spring Creek. The nearest flow gage is the USGS Gage No.12052500, located on the Quilcene River near Quilcene, approximately 13 miles west of the SR 3 culvert crossing.

The use of Kitsap County Public Utility District gages to develop flow rates for the Spring Creek PHD (Site ID 990395) was explored through a desktop exercise. Two gages that were identified as potential candidates to perform a Flood Frequency Analysis (Bulletin 17C; England et al. 2019) that has similar land cover and watershed characteristics as the Spring Creek site. The land use in these watersheds is more developed and urbanized than the Spring Creek watershed; however, due to heavy logging in the early 1990s of the Spring Creek watershed, the design team anticipated that runoff would be similar enough to develop flow estimates.

The two identified gaged locations are Dogfish Creek (DC) and Clear Creek West Tributary (CW). These gaged streams were ultimately considered not appropriate to use as a basin transfer. The DC gage has 19 full years of flow data (1991 to 1998 and 2012 to 2023), is located approximately 7 miles south of the Spring Creek crossing, and is the closest gage with a period of record long enough to provide an accurate result of a Bulletin 17c analysis (England et al. 2019). Annual rainfall is approximately 42.4 inches and the watershed encompasses approximately 3,200 acres; this is approximately an additional 9 inches of annual rainfall and 8 times the watershed size when compared to Spring Creek (33.9 inches of annual rainfall, 408-acre watershed). Because of the difference in average rainfall and watershed size, along with the distance from the site of interest, the DC gage was considered not appropriate for a basin transfer. The CW gage is located approximately 12 miles south of the Spring Creek crossing and has an annual average rainfall of 49.7 inches and 2,050 acres of contributing area to the watershed. The difference in rainfall and watershed size, as well as the distance from the Spring Creek crossing did not make it suitable for a basin transfer.

Peak flow estimates were developed using MGSFlood (MGS Software LLC. 2021) and validated using flow estimates from the USGS regression equations for Region 3 (Mastin et al. 2017). These are both hydrologic methods for ungaged locations described in WSDOT's *Hydraulics Manual* (2022b).

Both methods rely on the contributing area of the Spring Creek watershed. The Spring Creek watershed and subbasin boundaries were delineated using 3-foot resolution gridded LiDAR (USGS and Quantum Spatial 2018) and ArcHydro (ESRI n.d.) terrain-processing routines with ArcGIS software. Figure 2 shows basin and subbasin delineations. The site is located approximately 0.25 mile north of a separate WSDOT PHD (Site ID 991240) that is currently being developed by PACE Engineering; the adjacent boundary delineation was determined collaboratively. In addition to LiDAR terrain, culvert locations from the WDFW culvert database

(WDFW n.d.-a), Kitsap County Stormwater GIS data (Kitsap County 2017), and WSDOT field culverts (WSDOT 2021) were used to guide watershed and subwatershed boundary delineation. The resulting watershed is 409 acres (0.64 square mile) in size. No as-built plans or aerial imagery of surface water storage or other hydrologic facilities were identified within the Spring Creek watershed.

Due to the size of the watershed and varied terrain, the watershed was subdivided into six subwatersheds (990395A–990395F) based on terrain and tributaries (Figure 2). The terrain indicates that 990395D, 990395E, and 990395F drain directly to 990395B, and that 990395A, 990395B, and 990395C are ultimately conveyed through the SR 3 crossing and flow into Hood Canal. Table 6 lists the area of each subwatershed.

Table 6: Subwatershed contributing area[a]

Subwatershed	Area (acres)
990395A	43.6
990395B	23.1
990395C	26.8
990395D	91.2
990395E	36.4
990395F	187.4
Total	**409.0**

a. See Figure 2.

MGSFlood was selected as the primary flow development method because it incorporates more refined hydrology methods and inputs based on landcover, soil types, and underlying geology. Calculations for MGSFlood, using a 15-minute time step and the USGS regression equations, are provided in Appendix N. MGSFlood inputs are watershed areas associated with a combination of land cover, slope, soil type, and mean annual precipitation. Land cover was estimated based on National Land Cover Database (MRLC 2019a; Section 2.2). Slope was based on a 3-foot resolution gridded LiDAR (USGS and Quantum Spatial 2018). Soil type was estimated using a combination of Soil Survey Geographic Database (SSURGO) soils (NRCS USDA 2021; Section 2.3) and subsurface geology (NRCS USDA 2021; Section 2.3).

Soils identified as hydrologic soil group B/D were assigned a soil group B or “SAT” designation based on underlying geology. Areas with underlying till were assigned as soil group B, whereas areas with underlying outwash were assigned the SAT soil group. The slope class was assigned to each land cover and soil type based on a flat (0 to 5 percent), moderate (5 to 15 percent), or steep (>15 percent) slope based on 3-foot gridded LiDAR data. The mean annual precipitation used for MGSFlood calculations was identified as 36.5 inches, as determined by the 30-year climate normal (PRISM Climate Group, Oregon State University 2021).

The USGS regression equation inputs include watershed area and mean annual precipitation. The USGS regression equations also provide lower and upper prediction intervals (PI_l and $PI_{u,}$ respectively), acknowledging the uncertainty associated with this method.

Table 7 lists peak flow estimate results. MGSFlood results are generally similar (within approximately 36 to 19 percent) to the USGS regression equations central estimates. All values fell between the upper and lower confidence intervals for the USGS regression equations. The 2-year flow estimate was used to perform a simulation in the existing-conditions model in SRH-2D. The resulting top width of the model results were compared to field-measured BFWs within the reference reach. These comparisons showed modeled top widths that were slightly larger than measured widths, with some overbank flow. This comparison indicates that the estimated flows are generally similar to those expected based on these field indicators.

Field verification or validation of model conditions were based on the observations described in the hydraulic field report (Appendix B) and from past experience on similar crossings.

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. The largest risk to bridges and buried structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and to maintain passability for all expected life stages and species in a system.

WSDOT evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program (n.d.-a). All sites consider the projected 2080 percent increase throughout the design of the structure. Appendix G contains the projected increase information for the project site. The design flow for the crossing is 42 cubic feet per second (cfs) at the 100-year storm event. The projected increase for the 2080, 100-year flow is 44.1 percent, yielding a projected 2080, 100-year flow of 61 cfs.

Table 7: Peak flows for Spring Creek at SR 3

Mean Recurrence Interval	Selected Method - MGSFlood (cfs)	Check Method - USGS Regression Equation (Region 3) ([PI_l], Q_u, [PI_u] in cfs)
2	**7**	[5] 11 [21]
10	**24**	[10] 22 [45]
25	**33**	[13] 28 [60]
50	**38**	[14] 32 [72]
100	**42**	[16] 37 [84]
500	**43**	[19] 48 [120]
Projected 2080, 100	**(61; +44.1%)**	([27] 69 [173]; +44.1%)

4 Water Crossing Design

This section describes the water crossing design developed for SR 3 MP 58.49 Spring Creek to Hood Canal, including channel design, minimum hydraulic opening, and streambed design.

4.1 Channel Design

This section describes the channel design developed for Spring Creek to Hood Canal at SR 3 MP 58.49. The proposed design includes variability in the vertical, cross-sectional shape, and alignment; these elements are described in detail in the following sections.

4.1.1 Channel Planform and Shape

As mentioned in Section 2.7.1, the reference reach identified and considered in developing the preliminary design is located approximately 100 feet downstream of the culvert outlet and extends for another 100 feet downstream in a forested area with well-vegetated banks. Per the WCDG (Barnard et al. 2013) the planform and shape of each subreach within the proposed design were designed to mimic the reference reach with adjustments based on engineering and geomorphic judgements.

The proposed geometry includes a 5.5-foot BFW, which varies from the concurred BFW of 7.5 feet in Section 2.7.2. This geometry represents an observed channel width without the influence of LWM. The addition of wood and wood analogs is proposed and the expectation is that portions of the channel will widen over time to a similar BFW variability observed in the reference reach and to an average BFW closer to the concurrence value of 7.5 feet. The 5.5-foot BFW also mimics the hydraulic conditions commonly observed within the reference reach, specifically the velocities, depths, and width-to-depth ratio observed at the 2-year flow.

The bottom of the channel is flat and 30 inches wide, and then the channel slopes up at 2H:1V (horizontal:vertical) for 18 inches to provide benches for stability. The BFW channel has a depth of 9 inches, which will vary based on the field fit of a slightly sinuous low-flow channel and habitat complexity features discussed later in this section. The floodplain then slopes up at a 10H:1V slope to mimic what was roughly observed in the reference reach. The design flood is contained within the channel extents, but the stream engages its floodplain at more frequent occurrences (Figure 27). Each bank's floodplain width varies based on meander location within the structure, the need for adequate offset from the structure walls, and for the variability/ complexity of the channel, but the average width of the combined floodplain bench is 12.5 feet. A meander belt width assessment was performed to inform design of the minimum hydraulic opening. The amplitude was considered to drive the minimum hydraulic opening. Belt width was estimated by measuring the approximate perpendicular distance between lines drawn tangent at the apex of two successive meander bends. These perpendicular distances varied from 18 to 22 feet.

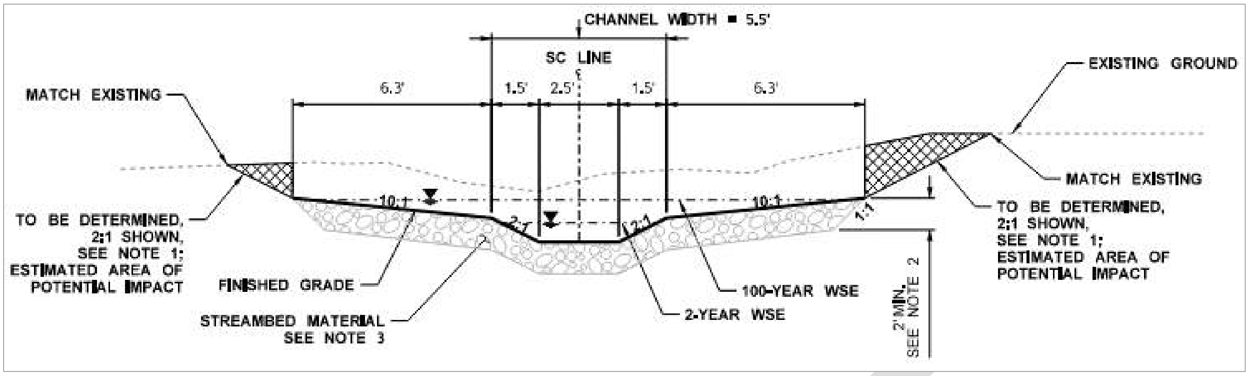

Figure 27: Design cross section

Inside the structure, the floodplain has a varying width of approximately 3.3 to 9.3 feet on either side of the channel. Outside of the structure, the floodplain has a width of 6.3 feet on either side of the channel and the graded surface slopes at 2:1 from the edge of the hydraulic opening to tie into the existing ground (Figure 27). Habitat boulders, cobble mix, and SWM are proposed to span the crossing at various locations within the channel to form step-pools that mimic the reference reach, which is discussed further in Section 4.3.2. See Appendix D for existing and proposed channel cross sections and planforms.

Although the proposed channel geometry differs from the reference reach, it will provide hydraulic characteristics similar to the reference reach. By modifying the channel shape, the channel’s frequent connection to the floodplain is ensured (Figure 28). Model results show that the water-surface elevation at the 2-year event flow is within 1 to 2 inches of the top of the channel at a BFW of 5.5 feet. Given the inherent uncertainty in assigned roughness values and conceptual nature of the cross section, this difference of 1 to 2 inches is acceptable. Furthermore, the 100-year velocity through the crossing is comparable to the velocity in the reference reach (as seen in Appendix H). The channel shape is expected to change as channel side slopes weather over time and sand is deposited on the falling limb of flood events. The proposed channel geometry and floodplain width combine to ensure continuity of channel processes by facilitating frequent floodplain inundation, hydraulic conditions that transport the sediment load, and flow depths and velocities that ensure fish movement.

In later stages of the project, a low-flow channel will be added that connects habitat features together so that the project is not a low-flow barrier. The low-flow channel will be as directed by the engineer in the field.

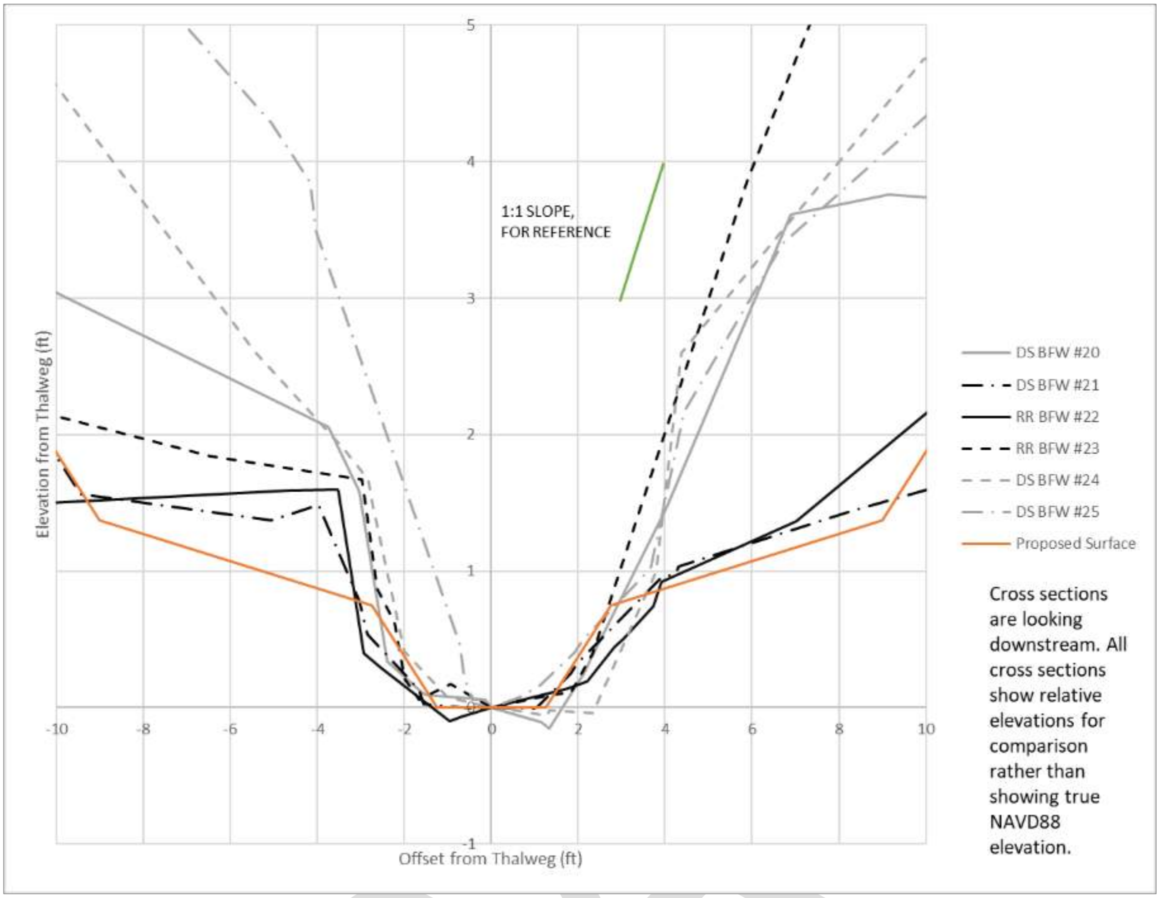

Figure 28: Proposed cross section superimposed with existing survey cross sections

4.1.2 Channel Alignment

A total of 128 feet of channel grading are proposed for the crossing—96 feet are within the crossing and the remaining 32 feet are outside of the crossing. In the existing conditions, the 36-inch culvert crossing runs at a skew to SR 3. The proposed alignment follows the existing 36-inch culvert alignment crossing SR 3. The proposed crossing alignment starts where the existing culvert inlet is located and follows the existing culvert for approximately 55 feet. Then, the proposed alignment bends both with a radius of curvature of 15 feet to provide a slight meander and runs parallel to the existing culvert for approximately 40 feet. The alignment then bends with a radius of curvature of 15 feet to tie back into the existing alignment. The meander mimics the general pattern observed in the local system upstream and downstream of SR 3 within the available survey limits. See Appendix D for existing stream meander pattern.

Sinuosity in the reference reach is 1.1, as noted in Section 2.7.2. The sinuosity of the proposed channel should approximately match the existing sinuosity. However, sinuosity was not a primary driver of either the minimum hydraulic opening or channel design due to the gradient of the channel. Steeper gradient channels (greater than roughly 3 to 4 percent) tend not to have well-developed meander bends and attendant significant sinuosity. Since the proposed channel gradient is 3.8 percent, sinuosity was not a driver of the design. However, meander belt width (the width between parallel lines that bracket the channel) was considered in, and is the controlling aspect of, the development of the minimum hydraulic opening.

The proposed structure will have, at a minimum, 3 feet of separation between the main channel banks and the edge of the cut slope or structure wall. The structure width is also set so that adequate width is provided for sediment transport and the habitat complexity features have room to adjust over time. The proposed plan and profile sheets are in Appendix D, and vertical variability is discussed further in Section 4.1.3.

4.1.3 Channel Gradient

The total gradient of the existing surveyed reach is 4.1 percent. The surveyed channel reach upstream of the existing culvert has an average slope of 3.8 percent. The WCDG (Barnard et al. 2013) recommends that the proposed crossing bed gradient be within 25 percent of the existing stream gradient upstream of the crossing. The proposed channel has an overall slope of 3.8 percent, giving a slope ratio of 1.0. This falls within the recommend 25 percent of the existing stream gradient. Additionally, the reference reach for the project has a gradient of 3.7 percent; therefore, the proposed gradient is within the 25 percent guidance for reference reach applicability. The proposed channel is comprised of discrete steps, treads, and pools with varying degrees of slope; the slope, layout, and dimensions of these features will be expanded on during the FHD and plans, specifications and estimates (PS&E) package development.

Long-term aggradation is not expected at the crossing. Despite upstream mass-wasting creating a chronic source of highly mobile sediment, the channel slope is sufficient to transport incoming sand fraction through the design reach. Given the steep slopes (3 to 5 percent) upstream and downstream of the crossing, observed sand sediments are likely deposited on the falling limb but readily mobilized at the next flood event. Additionally, the proposed channel would have an active floodplain, where incoming excess sediment can be deposited; this “relief valve” may limit in-channel deposition to less than 6 inches. Long-term degradation risk is not high, as the presently observed steps are expected to remain or reform in-kind to continue to hold the grade of the channel. Channel evolution through slow regrade of these steps will also attenuate long-term degradation. Additional information on long-term aggradation and degradation is provided in Section 7.2.

4.2 Minimum Hydraulic Opening

The minimum hydraulic opening is defined horizontally by the hydraulic width and the total height is determined by vertical clearance and scour elevation. This section describes the minimum hydraulic width and vertical clearance. Section 7 provides a discussion on scour elevation. Figure 29 illustrates the minimum hydraulic opening, hydraulic width, freeboard, and maintenance clearance terminology.

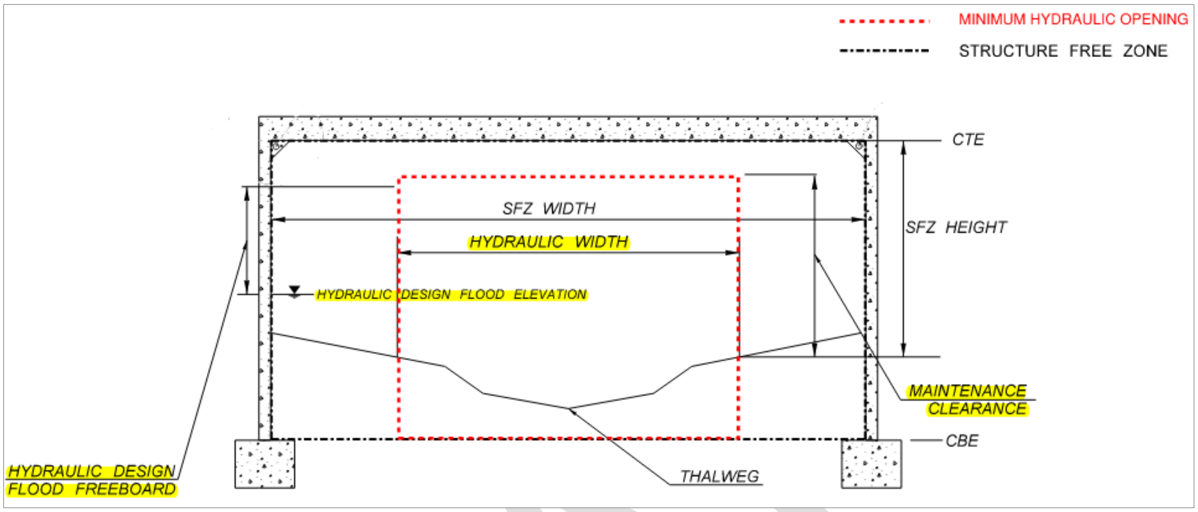

Figure 29: Minimum hydraulic opening illustration

4.2.1 Design Methodology

The proposed fish passage design was developed using the WCDG (Barnard et al. 2013) and the WSDOT *Hydraulics Manual* (WSDOT 2022b). WDFW's WCDG contains methodology for five different types of crossings: No-Slope Culverts, Stream Simulation Culverts, Bridges, Temporary Culverts or Bridges, and Hydraulic Design Fishways. The permanent federal injunction allows for the use of the stream simulation method and the bridge design method unless unsurmountable circumstances exist onsite (constraints of landownerships or infrastructure for example). Using the guidance in these two documents, the stream simulation design method was determined to be the most appropriate at this crossing because the stream simulation design should be considered for a site if any of the following should be met: a moderately confined channel, a BFW less than 15 feet, and an equilibrium stream slope.

Using the guidance in the WCDG (Barnard et al. 2013) and the *Hydraulics Manual* (WSDOT 2022b), the stream simulation design was determined to be the most appropriate. As noted in Section 2.7.2, the BFW does not exceed 12 feet in the observed reach. Sections 2.7.4 and 2.7.5 note that the existing channel appears to temporarily store sand deposited on the falling limb until the next flood event transports this material. Additionally, the FUR is less than 3.0 (Section 2.7.2.1), the proposed crossing is beyond the 10:1 length-to-width ratio (applicability of stream simulation methodology is discussed in Section 4.2.4), and the slope ratio does not exceed 25 percent between the existing channel and the new channel (Section 4.1.3). Minimum stream simulation design requirements are proposed to be greatly exceeded for the crossing due to other considerations discussed in future sections. Section 4.1.3 notes that the channel has low channel migration potential vertically and horizontally. Section 4.2.3 shows that the minimum hydraulic opening, with a wider floodplain than existing, is sufficient to allow for the BFW to increase over time due to climate change.

4.2.2 Hydraulic Width

The starting point for the minimum hydraulic width determination for all WSDOT crossings is Equation 3.2 of the WCDG (Barnard et al. 2013), rounded up to the nearest whole foot. For this crossing, with a 7.5-foot concurred BFW, a hydraulic opening width of 11 feet was determined to be the minimum starting point

Based on discussions with comanagers during the Site Visit 3 concurrence meeting (February 15, 2022), it was requested that the maximum observed BFW of 12 feet (at a pool) be considered in calculating the minimum hydraulic opening. If this upper end of the observed BFW range was considered for minimum hydraulic opening sizing, stream simulation Equation 3.2 from the WCDG (Barnard et al. 2013) would recommend a minimum hydraulic opening of 17 feet. However, the final determination of hydraulic opening was based upon the value of the measured meander belt width. The resulting structure width accommodates the observed range of BFW without approaching the structure walls. If future design results in a proposed structure that meets long culvert criteria, additional width may be necessary.

To accommodate the anticipated 100-year flow regime and to accommodate the observed meander belt width, the hydraulic opening is expanded to 18 feet. This width allows for the anticipated flow to remain within the channel cross section and floodplain and reduces the likelihood of entrainment along the structure walls or cut slope when combined with proposed channel complexity features. Table 8 shows the minimum hydraulic opening required for each metric compared to the chosen minimum hydraulic opening. Associated vertical clearance requirements are in Section 4.2.3 and hydraulic length is in Section 4.2.4.

Table 8: Minimum hydraulic opening summary

Metric	Minimum Hydraulic Opening (ft)
Equation 3.2 of the WCDG	11
Length: Width Ratio	11
Q100 Span	18
Meander Belt Width	18.2-22.5
Chosen	**18**

Based on the factors described above, a minimum hydraulic width of 18 feet was determined necessary to allow for natural processes to occur under current flow conditions. The projected 2080, 100-year flow event was evaluated. Table 9 compares the velocities of the 100-year and projected 2080, 100-year events.

Table 9: Velocity comparison for 18-foot structure

Location[a]	100-year velocity (fps)	Projected 2080, 100-year velocity (fps)
Upstream of structure (STA 16+41)	4.5	5.2
Through structure (STA 13+61)	5.3	5.8
Downstream of structure (STA 12+19)	4.0	4.2
Reference reach (STA 11+80)	5.2	5.6

a. Stationing based on proposed alignment shown in Appendix D plan sheets.

No size increase was determined necessary to accommodate climate change. For detailed hydraulic results see Section 5.4.

4.2.3 Vertical Clearance

The vertical clearance under a structure is made up of two considerations: freeboard and maintenance clearance. Both are discussed below, and results are summarized in Table 10.

The minimum required freeboard at the project location, based on BFW, is 3 feet above the 100-year water surface elevation (WSE) (Barnard et al. 2013; WSDOT 2022b). WSDOT requires 1 foot of freeboard for buried structures with a BFW of less than 8 feet and on all bridge structures unless otherwise approved by HQ Hydraulics. This crossing follows WSDOT's *Hydraulics Manual* for required freeboard for all buried structures with a BFW of less than 8 feet. For the freeboard requirement, the design team assumed that the crossing will be a buried structure.

WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at the 100-year WSE and the projected 2080, 100-year WSE. The WSE is projected to increase by 0.2 foot for the projected 2080, 100-year flow rate. The minimum required freeboard at this site will be applied above the projected 2080, 100-year WSE to accommodate climate resilience.

The second vertical clearance consideration is maintenance clearance. HQ Hydraulics determines a required maintenance clearance if a height is required to maintain habitat elements, such as boulders or LWM. If there are no habitat elements requiring maintenance clearance to maintain, the maintenance clearance is only a recommendation by WSDOT HQ Hydraulics, and the region determines the maintenance clearance required.

The channel complexity features within the structure include habitat boulders and SWM habitat features that may need to be maintained. Therefore, with concurrence from WSDOT HQ, the design team requires a maintenance clearance of 10 feet to allow for machinery to access and operate under the structure. Maintenance clearance is measured from the highest streambed ground elevation within the horizontal limits of the minimum hydraulic width.

Table 10: Vertical clearance summary

Parameter	Downstream face of structure	Upstream face of structure
Station[a]	12+96	13+92
Thalweg elevation (ft)	46.1	49.8
Highest streambed ground elevation within hydraulic width (ft)	47.5	51.2
100-year WSE (ft)	47.4	51.1
2080, 100-year WSE (ft)	47.6	51.3
Required freeboard (ft)	1.0	1.0
Required maintenance clearance (ft)	10.0	10.0
Required minimum low chord, 100-year WSE + freeboard (ft)	48.4	52.1
Required minimum low chord, 2080, 100-year WSE + freeboard (ft)	48.6	52.3
Required minimum low chord, highest streambed ground elevation within hydraulic width + maintenance clearance (ft)	57.5	61.2
Required minimum low chord (ft)	**57.5**	**61.2**
Recommended minimum low chord (ft)	**57.5**	**61.2**

a. Stationing based on proposed alignment shown in Appendix D plan sheets.

4.2.3.1 Past Maintenance Records

As mentioned in Section 2.1, WSDOT Area 2 Maintenance (Port Orchard) was contacted to determine whether there are ongoing maintenance problems at the existing structure because of LWM racking at the inlet or sedimentation. The maintenance representative indicated that there was no record of LWM blockage and/or removal or sediment removal at this crossing.

4.2.3.2 Wood and Sediment Supply

The Spring Creek watershed is mostly evergreen forest with little urban development or hydrologic modification (Figure 4). This undeveloped state enables recruitment of woody material to the channel. The riparian corridor of deciduous trees and shrubs is also a source of woody material, and smaller pieces (<2.5 feet in length and <6 inches diameter at breast height) appear transportable by the channel, based on observed wood in the channel. However, the relatively small width of the channel is such that inputs of LWM tend to become channel-spanning pieces rather than engaging with channel flow. Breakdown of LWM may be required before wood pieces are available for transport. With respect to sediment supply, hypothesized mass-wasting scarps upstream of the crossing and field observations of sandy sediments in the channel indicate abundant sediment supply. Field observations indicate that the incoming sediment supply ranges from small gravel to sand. However, significant long-term aggradation is not anticipated due to the steep gradient of the crossing. As stated in Section 2.2, logging occurred around 1985, which may have contributed to sedimentation of Spring Creek. However, major logging sites have not been observed since then. At this time, information about restoration activities and urban growth are unknown. The proposed conditions for the life of the project are expected to remain the same as they are now.

4.2.4 Hydraulic Length

A minimum hydraulic width of 18 feet is recommended up to a maximum hydraulic length of 180 feet. If the hydraulic length is increased beyond the 180-foot threshold, the design team will need to reevaluate the hydraulic width and vertical clearance. However, it is highly unlikely that the proposed hydraulic length would approach this threshold. At this time, no specific structure has been recommended.

4.2.5 Future Corridor Plans

Future corridor plans were requested from the WSDOT Project Engineer's Office by the design team on September 8, 2022. At the time of preparing this PHD, there are currently no long-term plans to improve SR 3 through this corridor.

4.2.6 Structure Type

No structure type has been recommended by WSDOT HQ Hydraulics. The layout and structure type will be determined at later project phases, though a buried structure is assumed.

4.3 Streambed Design

This section describes the streambed design developed for Spring Creek to Hood Canal SR 3 MP 58.49.

4.3.1 Bed Material

The modified Shields bed stability approach was used to design the streambed aggregate material, as it is the most suitable bed stability tool for the anticipated slope of the proposed channel (less than 4 percent). This method uses empirical streambed aggregate material stability equations to determine bed material incipient motion and selects the D_{50} or D_{84} mobilized at a particular design storm event to achieve stability (Barnard et al. 2013). Final gradations of the bed stability approach are provided based on standard WSDOT streambed aggregate sizes and compared against empirically based streambed aggregate distributions. The streambed aggregate mix calculations are in Appendix C.

As shown in Section 2.7.3 and Table 5, the pebble counts indicate that the stream is filled with mostly sand and small streambed sediment. The D_{50} ranges from 0.4 to 0.5 inches and the D_{84} ranges from 0.9 to 1.2 inches. This gradation is likely due to past mass-wasting occurring upstream of the crossing, creating landslide deposits, which present a chronic fine sediment source to the channel. To create the step-pool system noted in the reference reach and as necessitated by the channel geometry, the proposed bed will be comprised of stable, nondeformable steps with a deformable bed between steps, as suggested in the WCDG (Barnard et al. 2013). Similarly, "the larger particles in a natural step-pool channel are roughly similar in size to the depth of flow at its bankfull conditions" (Barnard et al. 2013). In addition to gradations for the steps, pools, and treads, a gradation for the floodplain was also developed. The purpose of this gradation is to ensure that the floodplain is resistant to avulsion and incision at high flows.

For this channel, the following three separate gradations are proposed (Table 11):

1. Main Channel Gradation – The proposed gradation for the pools and step treads will more closely follow what was seen in the pebble counts, with a D_{50} of 0.5 inch and D_{84} of 2.2 inches (Table 11). The proposed gradation consists of a combination of three different WSDOT gradations: 20 percent streambed sand, 60 percent streambed sediment, and 20 percent 4-inch cobbles. The D_{50} is within 20 percent of the observed $D_{50,}$ but the D_{84} exceeds the 20 percent variation. The observed D_{84} is influenced by the high sand fraction present in the bed and at the PHD stage, the subsurface substrate was not investigated to determine if the sand fraction is a thin veneer covering a coarser bed material. This should be investigated at the FHD. The modified Shields approach shows that the proposed pool and step treads D_{100} is mobile at the 2-year event.

2. Floodplain Gradation – A separate floodplain gradation is proposed to mitigate the risk of channel avulsion and incision into the newly constructed floodplain without over coarsening the floodplain. Although this gradation is similar to the channel gradation, woody debris will be added to the floodplain to increase roughness and further limit risk of avulsion. The proposed floodplain gradation will be similar to the main channel gradation, except the D_{50} is approximately 0.7 inch. The proposed gradation consists of a combination of three different WSDOT gradations: 20 percent streambed sand, 50 percent streambed sediment, and 30 percent 4-inch streambed cobbles. Based on the modified Shields approach, the floodplain gradation D_{50} will be mobile at the 2-year and the D_{100} will be mobile at the anticipated 100-year flow event. This roughly follows the design methodology for the main channel gradation.

3. Step Gradation – In this case, the bankfull depth is 0.9 foot in the reference reach; therefore, the design team anticipates a step D_{84} of 8 inches and D_{100} of 12 inches (Table 11). The proposed gradation is 50 percent WSDOT standard streambed mix and 50 percent 12-inch cobble mix. The design team anticipates that these larger particles will remain immobile during the design flow and add complexity as the channel reshapes itself as the other two "mobile" gradations reform around the steps. SWM collects on and between the larger particles in this gradation and on habitat complexity boulders, further enhancing complexity, which is discussed further in Section 4.3.2. This should allow the channel to retain its general planform and fish passability but evolve over time. The modified Shields approach shows that the proposed step D_{50} is incipient and the D_{84} is stable at the 2-year event, and the step D_{50} and the D_{84} is mobile at the 100-year events. However, further sensitivity analysis indicates that in the presence of Type 1 and Type 2 habitat boulders in the step at a proportion roughly equal to one half the step gradation mix would result in the D_{50} being marginally stable at the 2-year event.

The main channel and floodplain gradations will incorporate a small and similar fraction of SWM to provide the stream with materials to adjust naturally after construction, and to help equalize roughness across the span of the proposed channel to prevent avulsion. The step gradation will use SWM to form wood and rock forced steps, which is discussed further in Section 4.3.2.

Due to the size and nature of the sediment supply and transport capacity, this system is determined to be a low risk, according to the Streambed Material Decision Tree in WSDOT's *Hydraulics Manual* (2022b). The PHD recommends that the material through and downstream of the crossing be placed in lifts and washed with fines to fill in void space; this will be considered further in the FHD. As mentioned in Section 2.4, the stream width, depth, gradient, and substrate are modeled as suitable for rearing, migration, and spawning of coho salmon, steelhead trout, and cutthroat trout, both sea run and resident.

Table 11: Comparison of observed and proposed streambed material

Sediment size	Observed diameter for design (in / mm)	Proposed main channel diameter (in / mm)	Proposed floodplain diameter (in / mm)	Step diameter (in / mm)
$\mathbf{D_{16}}$	0.1 / 2.5	0.02 / 0.42	0.02 / 0.42	0.18 / 4.5
$\mathbf{D_{50}}$	0.5 / 12.7	0.5 / 12.7	0.7 / 17.8	2.0 / 50
$\mathbf{D_{84}}$	1.1 / 27.9	2.2 / 56	2.2 / 57	8.0 / 203
$\mathbf{D_{95}}$	1.6 / 40.6	3.0 / 76	3.1 / 79	10.0 / 254
$\mathbf{D_{100}}$	3.7 / 94.0	4.0 / 102	4.0 / 102	12.0 / 305

4.3.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for Spring Creek to Hood Canal SR 3 MP 58.49.

4.3.2.1 Design Concept

A mix of treatments that reflect the complexity observed in the reference reach are proposed for the channel in, upstream, and downstream of the crossing. In the reference reach, different hydraulic conditions are created in the step, pool, and tread (meaning the riffle, run, or glide separating pools and steps). This same channel assemblage is proposed for the channel through the crossing (Figure 30). Specific elements of the complexity include the following:

- Variation in channel types
  - Step, pool, tread (riffle, run, glide)
- LWM and SWM
  - LWM structure upstream and downstream of the crossing (not within the structure)
  - SWM embedded in the channel bed in the crossing. The SWM size should vary to promote greater complexity; it cannot exceed 4 inches in diameter or 6 feet in length.
- Habitat boulders
  - Type 1 and Type 2 rounded boulders strategically used to promote the formation of steps and channel complexity within the structure.

SWM will be incorporated into the streambed mix, at a percentage that allows for bed sealing. More small wood would be added on the surface and in the step-pool crests, as shown on Figure 30. The purpose of this wood is to give the stream the ability to naturally form intermediate woody steps between rock-forced steps, as seen in the reference reach.

Steps in the reference reach are formed by live and dead woody material and exhumed boulders not considered part of the sediment load. Steps proposed as part of the channel within the crossing are formed by SWM, the step material gradation (Section 4.3.1), and the habitat boulders referenced above. These boulders are similar to those observed in the reference reach but are not part of the sediment load and are not the predominant step-forming element. Over time, steps may accrete additional SWM and organic debris, similar to steps observed in the reference reach. Within the structure, small, rounded boulders; rounded cobble, and SWM will be used to provide habitat complexity and form steps. Step height is limited due to the maximum hydraulic drop being limited to 0.8 foot to prevent fish stranding, as specified in WDFW's WCDG (Barnard et al. 2013). Additional complexity beyond the step is provided by the strategic placement of habitat boulders and SWM.

The steps in the channel are designed to be nondeformable but the bed material in the pools and treads are deformable. As mentioned above, the steps include SWM, the step material gradation, and habitat boulders. Step-pool crests will consist of larger rocky material sized such that the D_{50} is stable at the 100-year event. Ideally, this can be accomplished using 12-inch cobble mix with at least 30 percent standard streambed aggregate material to ensure bed sealing.

Habitat boulders will be used to the minimum extent necessary to promote the desired complexity, both as part of steps and separate from steps. Habitat boulders are proposed to create stream diversity similar to what was observed in the reference reach. Figure 30 shows the conceptual layout of habitat boulders within the proposed structure.

These step-pools with tread units have not been incorporated into the proposed design, outside of a conceptual detail, due to the nature of this PHD and project delivery process (progressive design-build).

We anticipate that additional detail will be added to the habitat complexity design during the FHD process, including specific placement of habitat features within the channel, vertically varying profile (incorporating metrics for steps and pools), varying horizontal cross sections, SWM incorporated into the habitat features, and the resulting hydraulic complexity of the addition of these elements.

The LWM structures are placed to engage with the channel at all flows. Crests within the profile are created by deformable steps. These steps mimic the observed steps, which commonly consist of tree roots and organic debris accumulations and enable flatter gradient glides to form, just as observed in the reference reach.

LWM is specified in the WSDOT right-of-way upstream and downstream of the crossing. LWM is designed according to WSDOT (2022b) and Fox and Bolton (2007). LWM should meet and exceed the sizing and characteristics of the reference reach by enhancing habitat, geomorphic function, sediment storage, bank stability, and hydraulic roughness. Due to the location and size of the tributary, the site is not likely used for recreation, swimming, or boating. Potential current and future use for fishing may occur, thus the LWM would be low impact to the recreational user.

The LWM design shows the proposed 30 pieces of wood to be placed within the WSDOT right-of-way (Figure 31). This includes the 128-foot graded channel, with the exception of a 96-foot segment for the roadway crossing. No LWM is recommended within the proposed crossing structure. As previously noted, SWM is proposed within the crossing to facilitate habitat development and complexity. Small wood can pass through the structure; it can rack onto LWM structures downstream, form step-pools downstream, or lodge itself into the banks downstream to extend the reach of channel complexity improvements beyond the project limits.

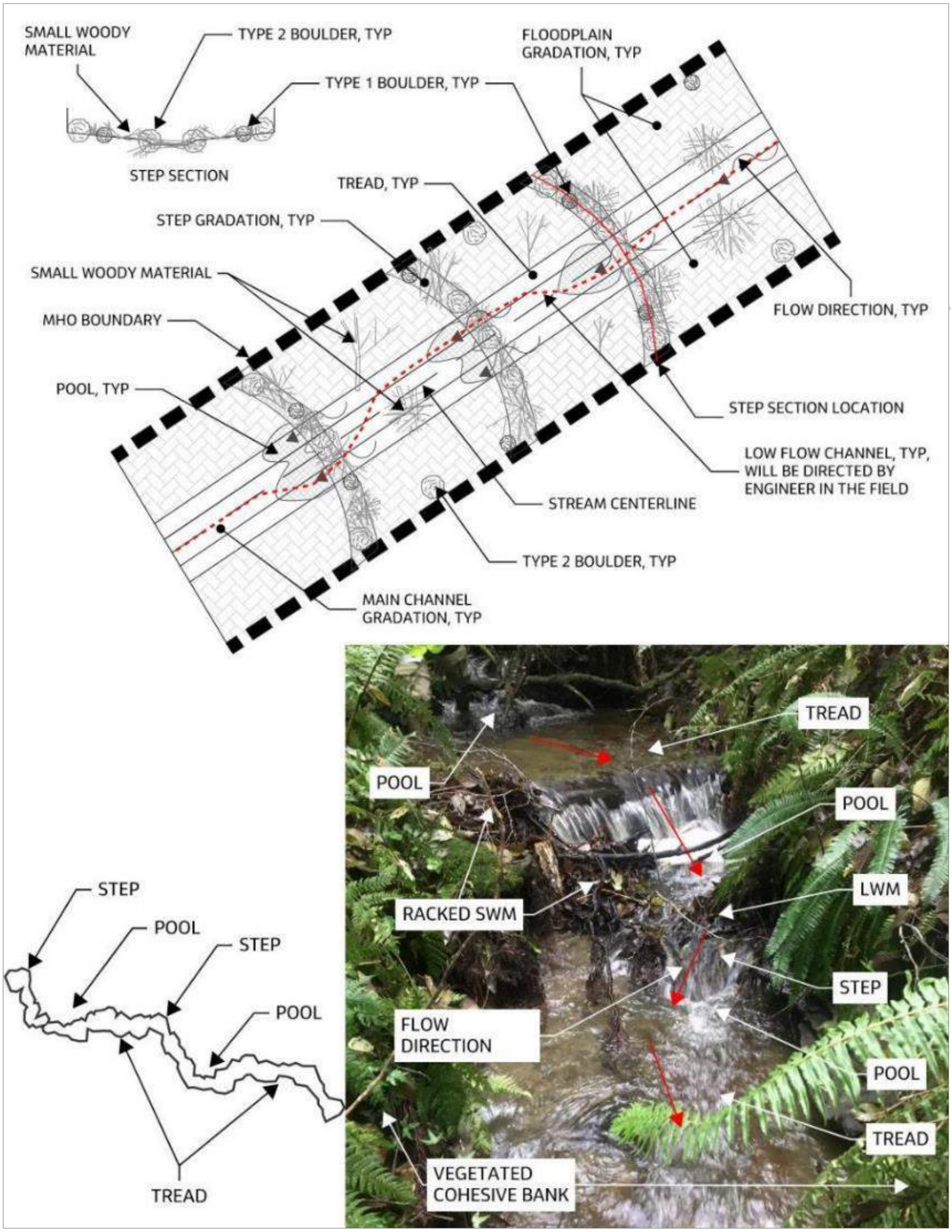

Figure 30: Habitat complexity features

Currently, the LWM design is conceptual and will need to be field verified in the FHD. The proposed design meets and exceeds the 75th percentile of the number of key pieces and total number of pieces, as estimated by Fox and Bolton (2007), in addition to the total wood volume. Table 12 provides a comparison of the Fox and Bolton targets and the proposed design values of LWM. Table 13 lists the properties of the logs used for the LWM structures. Appendix F contains the LWM calculations.

Table 12: Project reach LWM loading

LWM Loading Component	Design Criteria (75th percentile)[a]	Design Criteria (50th percentile)[a]	Proposed Design
Total pieces (quantity)	15	11	30
Total volume (cubic yards)	50.5	26	51.3
Key Pieces (quantity)	4	2	12

a. Calculated based on Fox and Bolton (2007) metrics using a project reach of 128 feet and a concurrence BFW of 7.5 feet.

Table 13: LWM structure log types

Log Type	Length (ft)	Diameter at breast height (ft)
Type A	25	2.2
Type B	20	1.3
Type C	15	1.0

The proposed LWM structures may be either surface placed or partially buried to ensure engagement with the stream The types of LWM structures are as follows:

Type 1: These structures consist of two Type A pieces placed in a “V” shape with a Type C piece placed at a skew on top of it. In this structure, the root wads engage with the low-flow channel. The larger size of these pieces ensures that their geometry remains intact, resulting in persistent local scour and deposition features around the root wads.

Type 2: These structures consist of two Type B pieces, with one parallel to the channel and one perpendicular. A Type A piece is placed on top of the parallel piece next to the perpendicular piece. This structure engages with the channel in the longitudinal direction, meaning that flow is along the long axis of one of the medium pieces. This configuration was observed in the field upstream of the crossing and resulted in bedform changes (i.e., diversity).

Type 3: These structures consist of two Type C pieces placed in a “V” shape with a Type B piece placed at a skew under it. This structure type is a similar configuration to the Type 1 structure, but the smaller pieces are subject to movement in place, meaning rotation, such that bedforms created by local scour and deposition are dynamic as the piece(s) rotate or shift.

LWM anchoring is anticipated until stability calculations are completed that indicated otherwise. At the FHD, all structures will be confirmed to remain stable up to and through the 100-year flow event by either anchoring or by virtue of the structures’ weight, configuration, and orientation. It is imperative that placed LWM will not negatively impact the downstream landowners crossing.

No LWM structure type is designed to change channel planform but rather facilitate in-channel change, such as local scour and deposition. Preformed pools are recommended around larger rootwads to anticipate future scour. All habitat components of the proposed LWM design include providing habitat through partial channel-spanning LWM, thus promoting pool creation and maintenance, resulting in refugia formation as well as shade and food-sourcing promotion of aquatic organisms for fish. LWM is generally mimicking trees that have fallen into the channel, either by windfall or by being undercut. Cross logs are added to provide ballast. The proposed channel was designed to maintain a low-flow area; however, a seasonable hydrologic analysis was not performed as the channel complexity features will promote concentrated low-flow areas to reduce fish stranding.

The proposed design improves ecological diversity by providing LWM that interacts with the active channel and a more heterogenous channel, which provides instream habitat for aquatic organisms. Additionally, all of the proposed LWM is assumed to be surface placed and self-ballasted rather than buried, which allows for a lesser grading and clearing impact. With a smaller footprint, more riparian vegetation can remain in place and continue to function properly, with a well-developed root mass to help stabilize banks, a well-developed canopy to provide shade and LWM recruitment, and a developed understory.

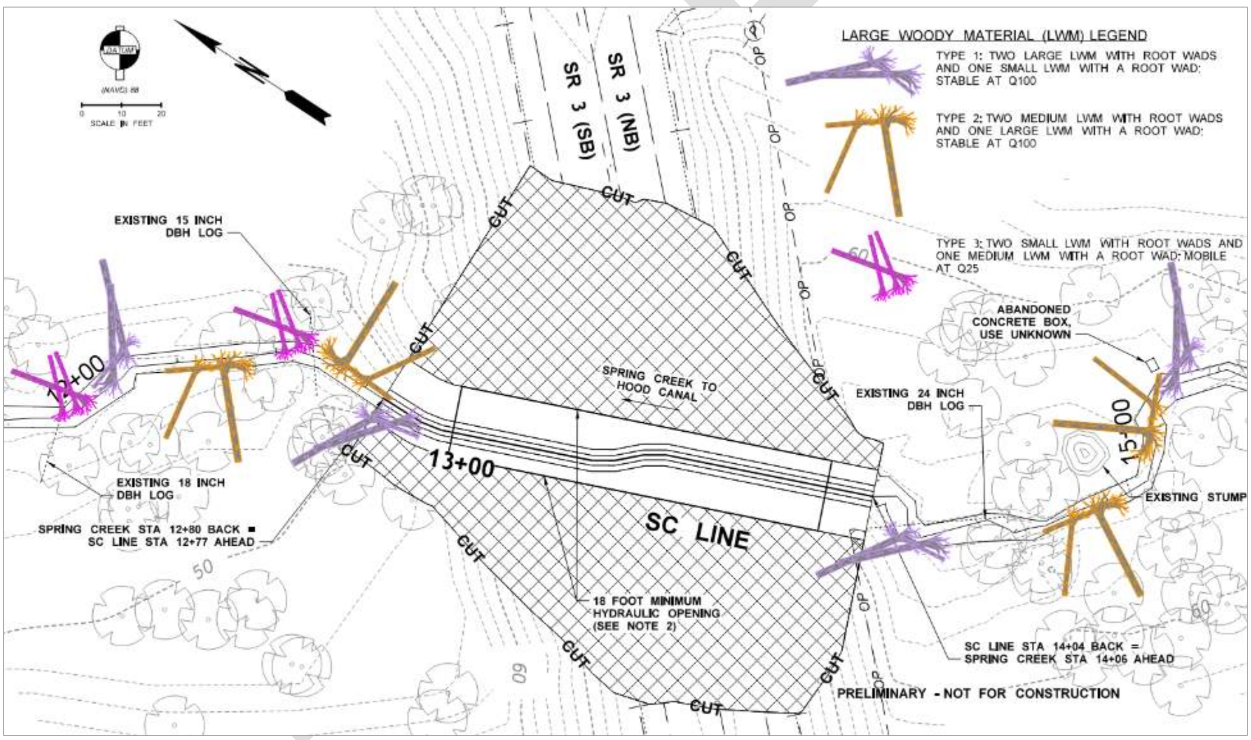

Figure 31: Conceptual layout of habitat complexity

4.3.2.2 Stability Analysis

Large wood stability analysis will be completed at final design.

5 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 3 Spring Creek crossing was performed using the U.S. Bureau of Reclamation's (2020) SRH-2D Version 3.3.1 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model. Pre- and post-processing for this model was completed using SMS Version 13.1.23 (Aquaveo 2022).

Two scenarios were analyzed for determining stream characteristics for Spring Creek with the SRH-2D models: (1) existing conditions with the 36-inch-diameter culvert and (2) proposed conditions with the proposed 18-foot-wide minimum hydraulic opening crossing installed. Appendix H provides a complete set of output figures.

5.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

5.1.1 Topographic and Bathymetric Data

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the WSDOT Project Engineer's Office, which were developed from topographic surveys performed by WSDOT on January 7, 2022. The survey data were sufficient to categorize the channel and floodplain, and no supplemental LiDAR data were necessary. Proposed channel geometry was developed from the proposed grading surface created by Jacobs. All survey information is referenced against NAVD88.

Surveyed pieces of LWM were parameterized as obstructions with defined end elevations and thicknesses. There are also two low (<2 feet), wood-forced steps within the model domain, one approximately 175 feet upstream of the existing culvert inlet and one approximately 160 feet downstream of the existing culvert outlet. The surveyed crest elevation of these steps are represented in the existing surface. Apart from these noted features, there are no other known hydraulic controls, barriers, or nearby infrastructure within the survey extents.

5.1.2 Model Extent and Computational Mesh

A mesh representing the topography of the project area was created for the existing and proposed conditions. The model mesh is a network of triangles and quadrilaterals that make up the computational cells (elements) of the model in which model results are computed.

The existing- and proposed-conditions model meshes include approximately 17,700 and 22,100 elements, respectively, across an area of approximately 1.1 acres (Figure 32 and Figure 34). The majority of the channel mesh was constructed with quadrilaterals that are approximately 1 to 2 feet wide, varying with channel width, and 1 to 3 feet long in the main channel; the overbank bank mesh was constructed with triangles with edge lengths that vary from 1 foot near the main channel to 4 feet at the exterior of the model domain. The quadrilateral main channel is modeled with at least seven elements across to sufficiently capture the channel within the mesh.

The existing- and proposed-conditions meshes vary in the vicinity of the SR 3 crossing, as shown on Figure 33 and Figure 35, respectively. The two meshes are consistent elsewhere in the model domain.

Survey data extend approximately 270 feet upstream and 290 feet downstream of the existing SR 3 crossing. The existing alignment starts at Station (STA) 10+00 at the beginning of the channel survey. The model extents span the surveyed area, and the upstream and downstream limits are sufficiently far away from the crossing to not influence hydraulics at the SR 3 crossing.

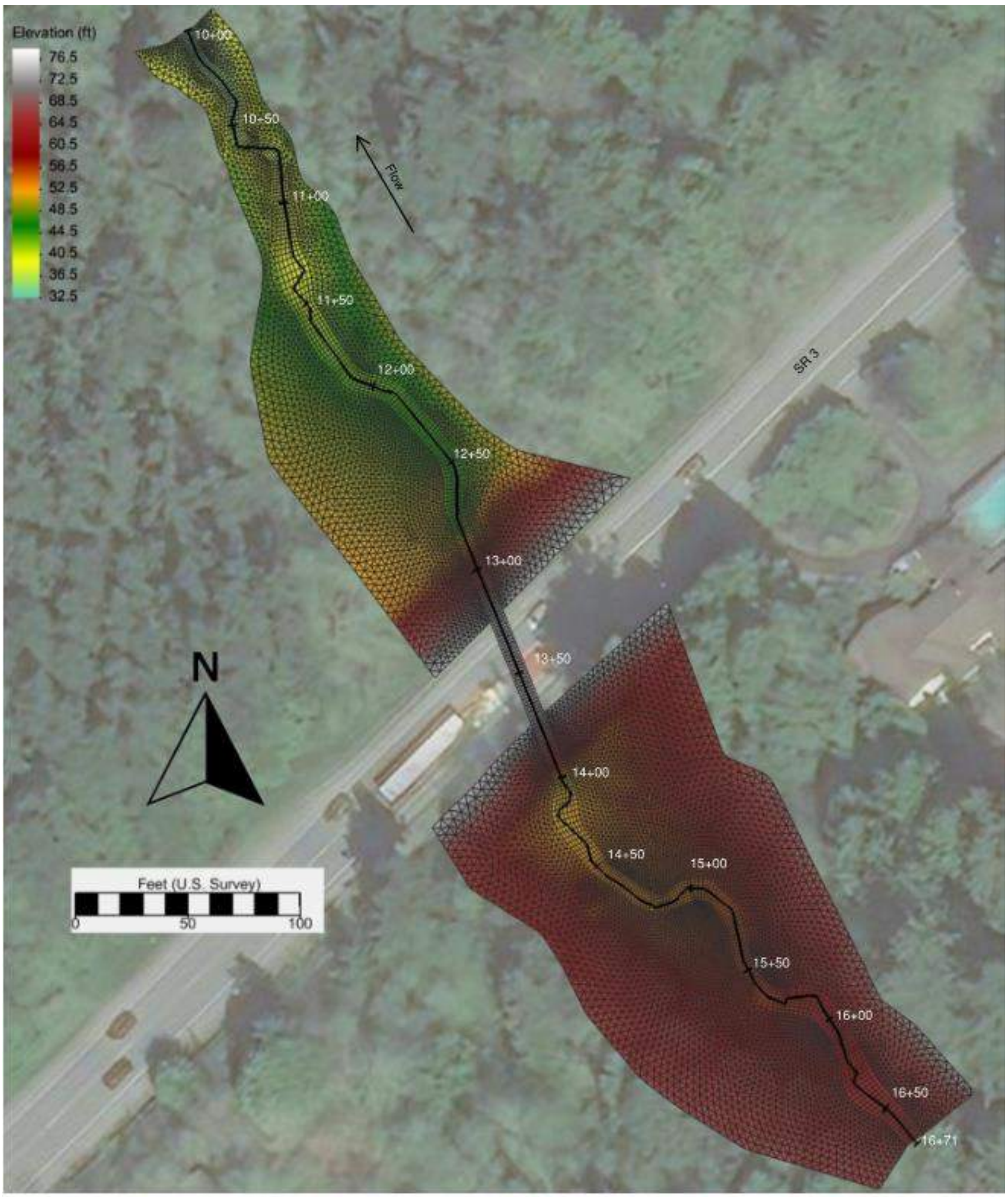

Figure 32: Existing-conditions computational mesh with underlying terrain for entire model domain

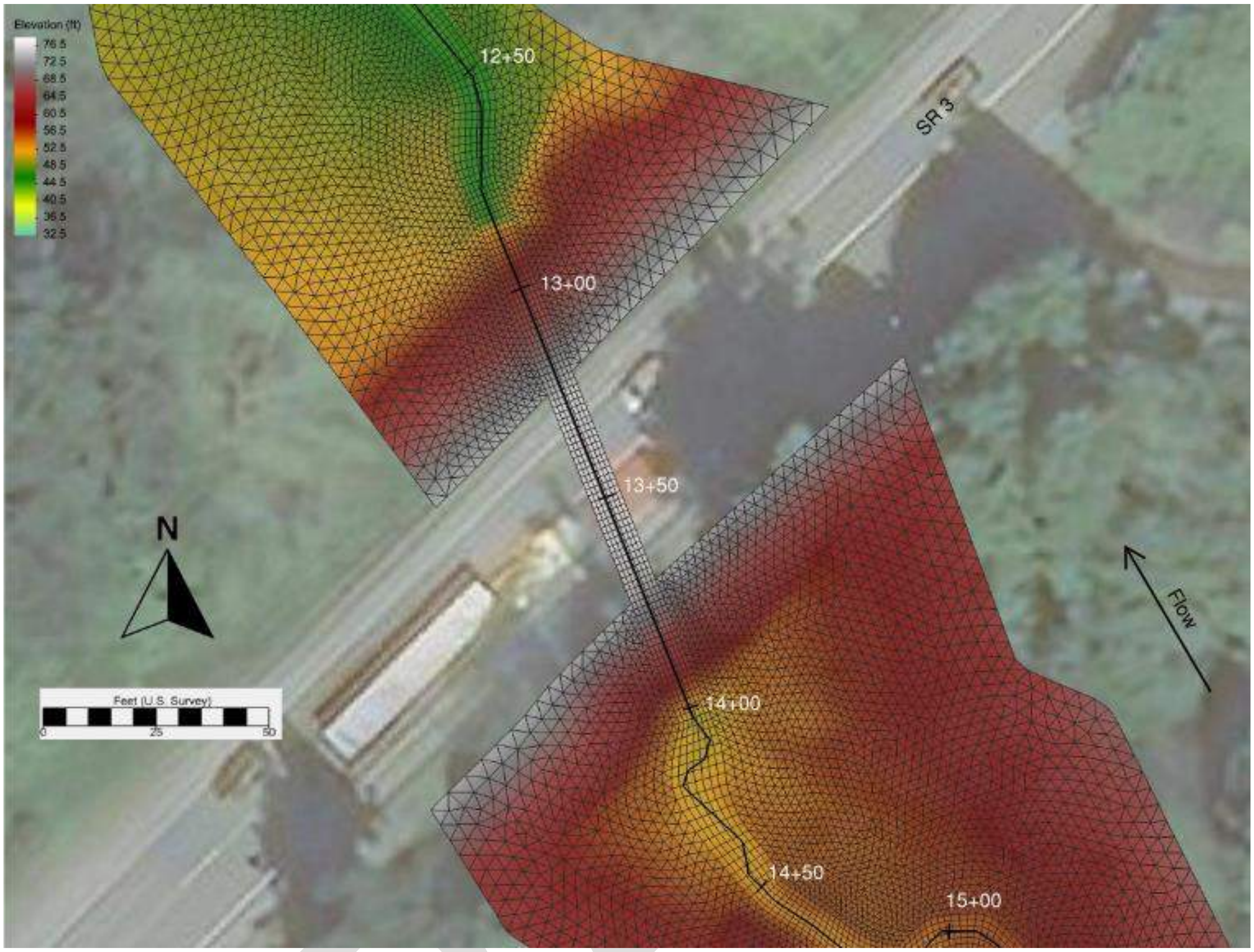

Figure 33: Existing-conditions computational mesh with underlying terrain zoomed in on crossing

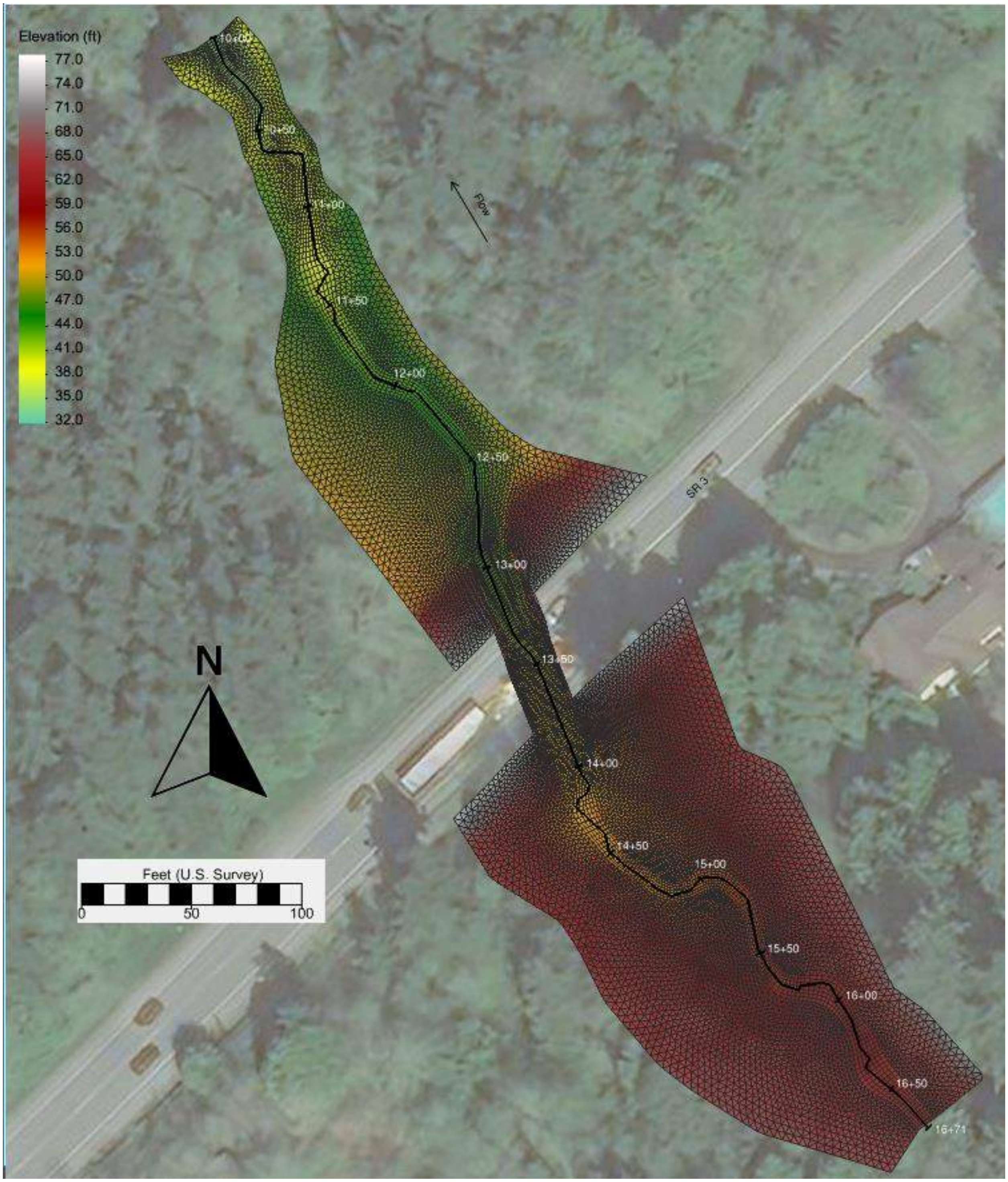

Figure 34: Proposed-conditions computational mesh with underlying terrain for entire model domain

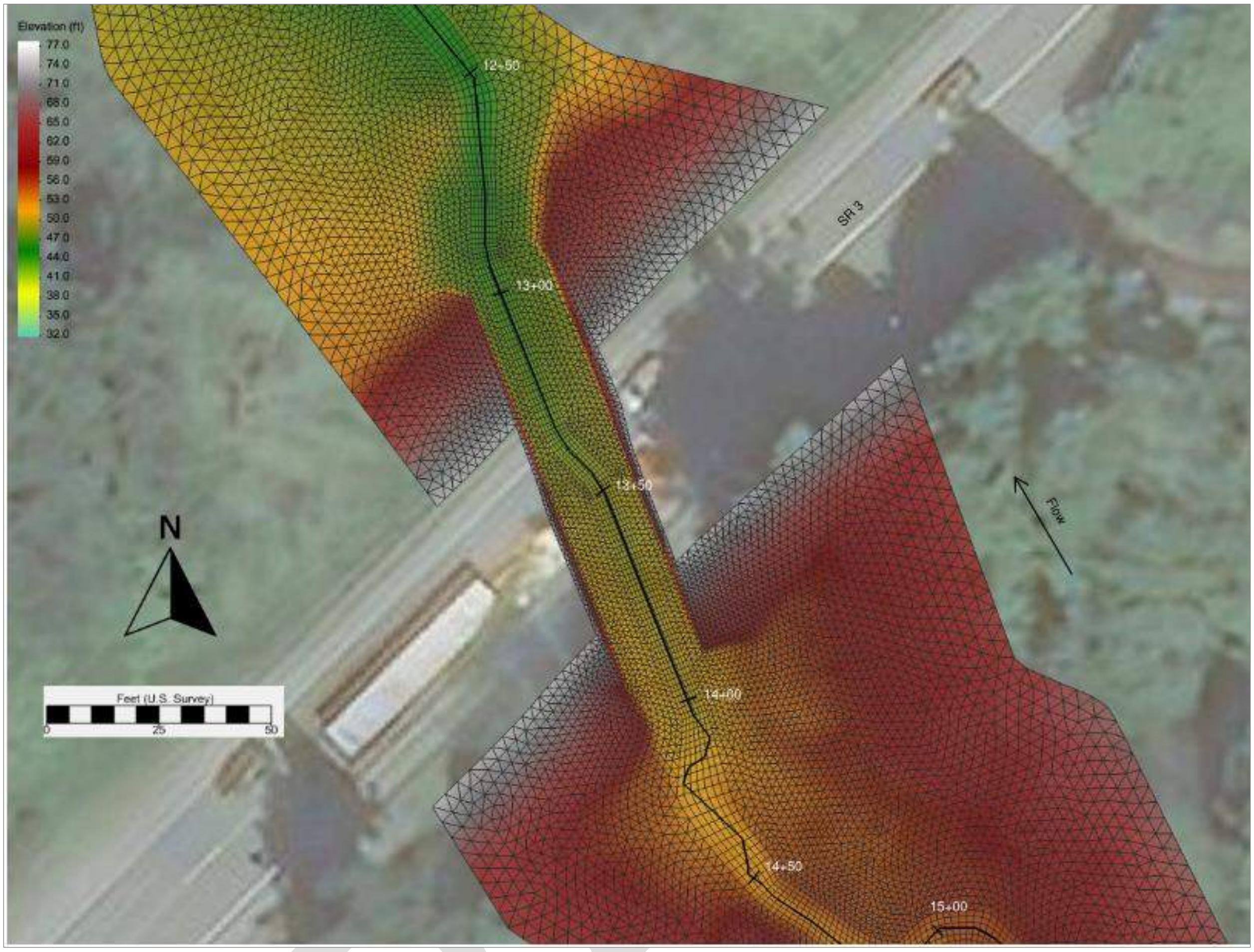

Figure 35: Proposed-conditions computational mesh with underlying terrain zoomed in on crossing

5.1.3 Materials/Roughness

The roughness coefficient is a composite value representing two forms of flow resistance: form roughness and skin friction. Both affect hydraulic conditions (such as WSE, velocity, and shear stress) and the energy that is available to transport sediment. Form drag represents large-scale impediments to flow, including bedforms, bends, point bars, LWM, or vegetation, and is highly dependent on flow depth and velocity. Skin (or grain) friction are the individual particle characteristics interacting with fluid at the fluid/soil boundary.

Roughness coefficients were estimated based on a combination of site observations, standard tabulated values, photographic guidance, and a semiquantitative prediction method. Manning's *n* values for the existing channel, overbank, and floodplain were determined using the Arcement and Schneider Method (1989), which is a semiquantitative procedure to account for flow resistance in streams due to channel irregularity, obstructions, vegetation, and meandering. Proposed LWM is parameterized as discrete high roughness (Table 14), and the constructed channel's step-pool design is represented as a composite *n* value through the proposed structure that is 10 percent rougher than the existing channel. A localized region of elevated roughness was also included at the existing culvert outlet for the sake of model stability ("Culvert Outlet" in Table 14). The roughness value for the interior of the existing culvert was set as 0.014 in HY-8, a typical value for concrete pipe.

Spatial distributions of roughness values in the existing- and proposed-conditions models are shown on Figure 36 and Figure 37, respectively.

Table 14: Manning's *n* hydraulic roughness coefficient values used in the SRH-2D model

Material	Existing Conditions Manning's *n*	Proposed Conditions Manning's *n*
Existing Channel	0.048	0.048
Constructed Channel	—	0.053
Overbank	0.061	0.061
Forested Floodplain	0.078	0.078
Culvert Outlet	0.080	—
Pavement	0.015	0.015
Large Wood Structure	—	0.480
SR 3 Culvert (Existing)	0.014	—

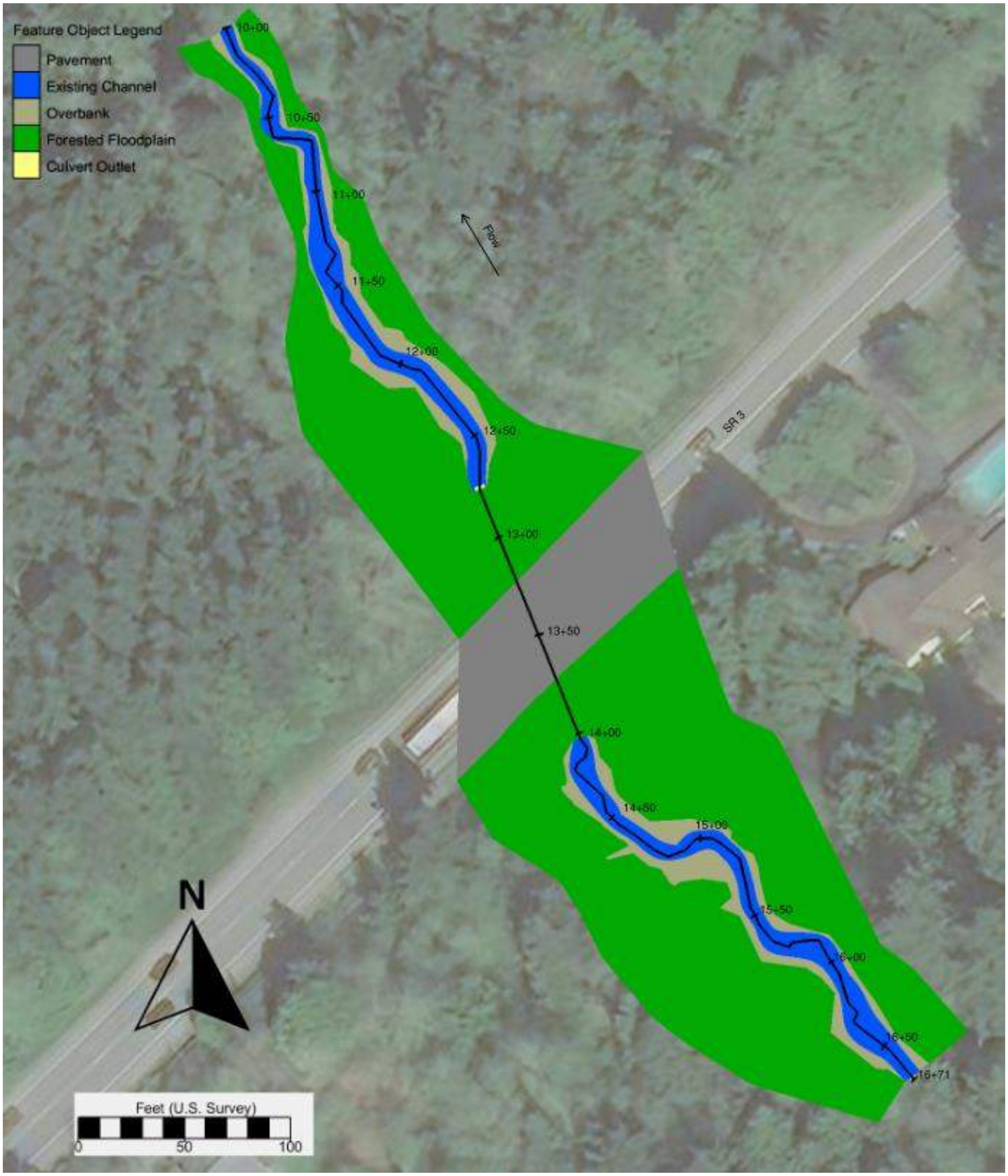

Figure 36: Spatial distribution of existing-conditions roughness values in SRH-2D model

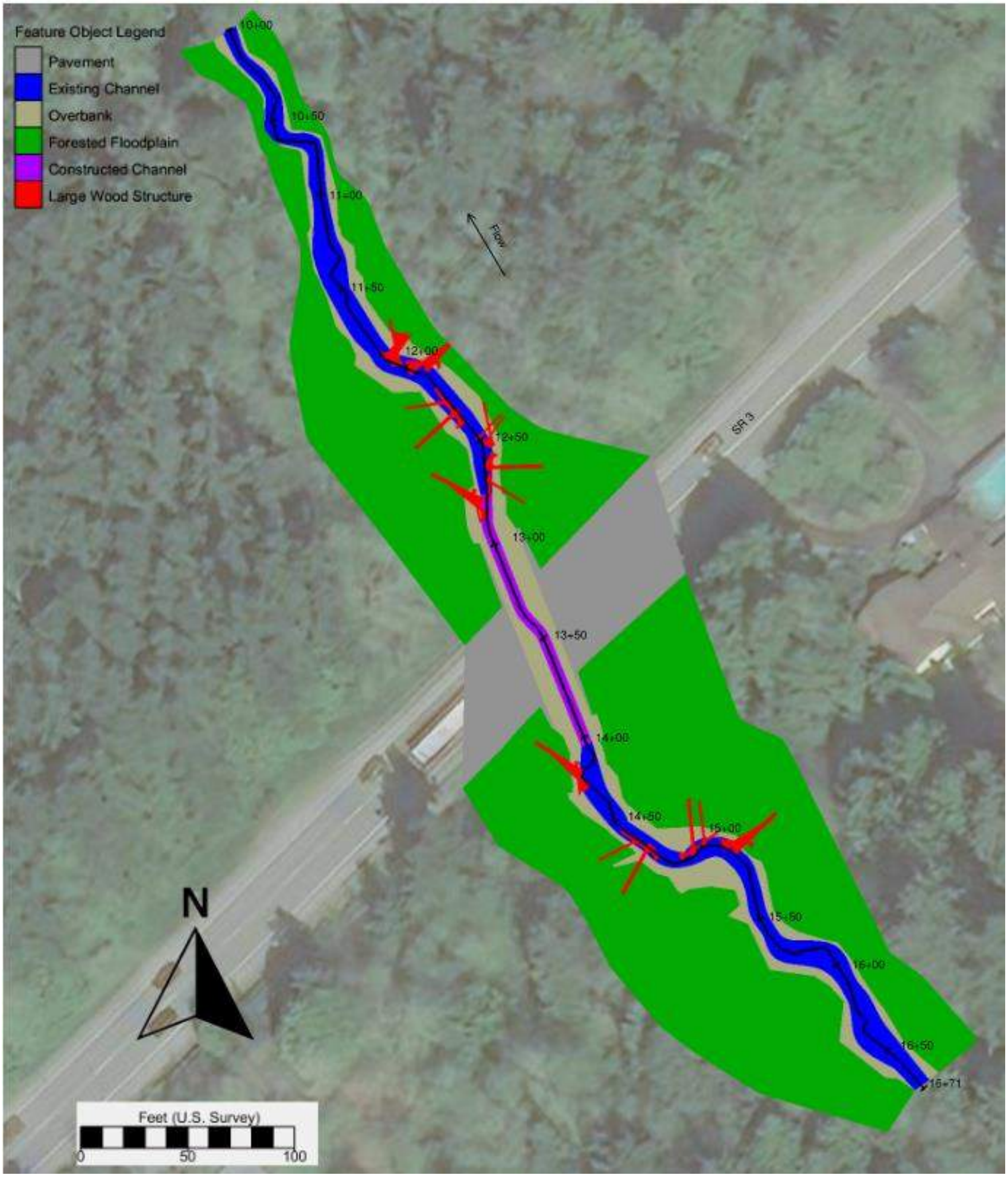

Figure 37: Spatial distribution of proposed-conditions roughness values in SRH-2D model

5.1.4 Boundary Conditions

The boundary conditions coverage in SMS was developed to account for flow into the system and flow out of the model domain. The inflow boundary condition for the existing and proposed conditions is an arc spanning the Spring Creek main channel at the southeast end of the model domain. The 2-year, 100-year, 500-year, and projected condition 2080, 100-year flows in Table 7 are input at this boundary arc. For the 2-year event, the inflow is a constant discharge. For all other flood events, the inflow is a time series hydrograph that includes 3 hours of ramp-up time before coming to a quasi-steady-state at the peak flow rate. The downstream outflow boundary for existing and proposed conditions is one arc spanning the main channel at the northwest end of the model domain. A constant WSE was calculated at this boundary for each flood event based on a normal depth assumption, a composite Manning's *n* value, slope, and flow (Figure 38). As the downstream boundary is 290 feet from the SR 3 crossing and the channel slope varies from 2 to 6.4 percent, the downstream boundary is sufficiently far downstream to not influence hydraulics through the proposed crossing.

The existing culvert crossing at SR 3 was modeled using HY-8 culvert boundary condition arcs (Federal Highway Administration 2021). The HY-8 parameters for the existing SR 3 crossing culvert are shown on Figure 39. Figure 40 and Figure 41 show the locations for all boundary conditions for the existing and proposed models, respectively.

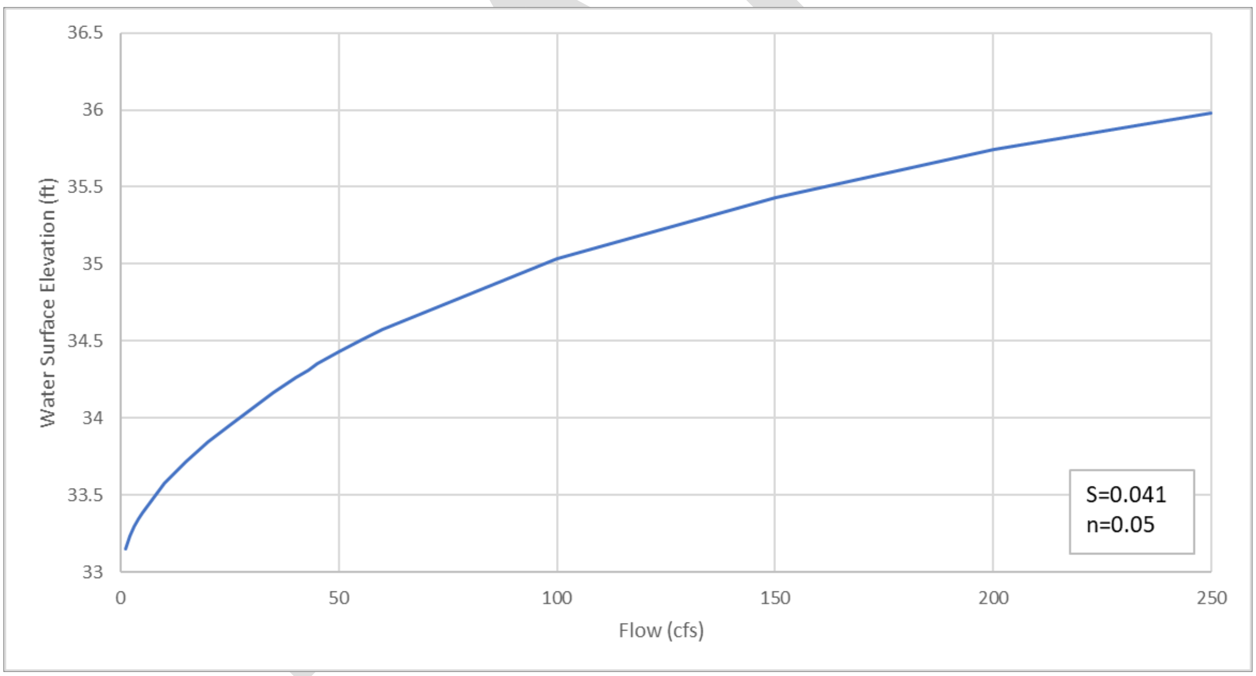

Figure 38: Downstream outflow boundary condition normal depth rating curve

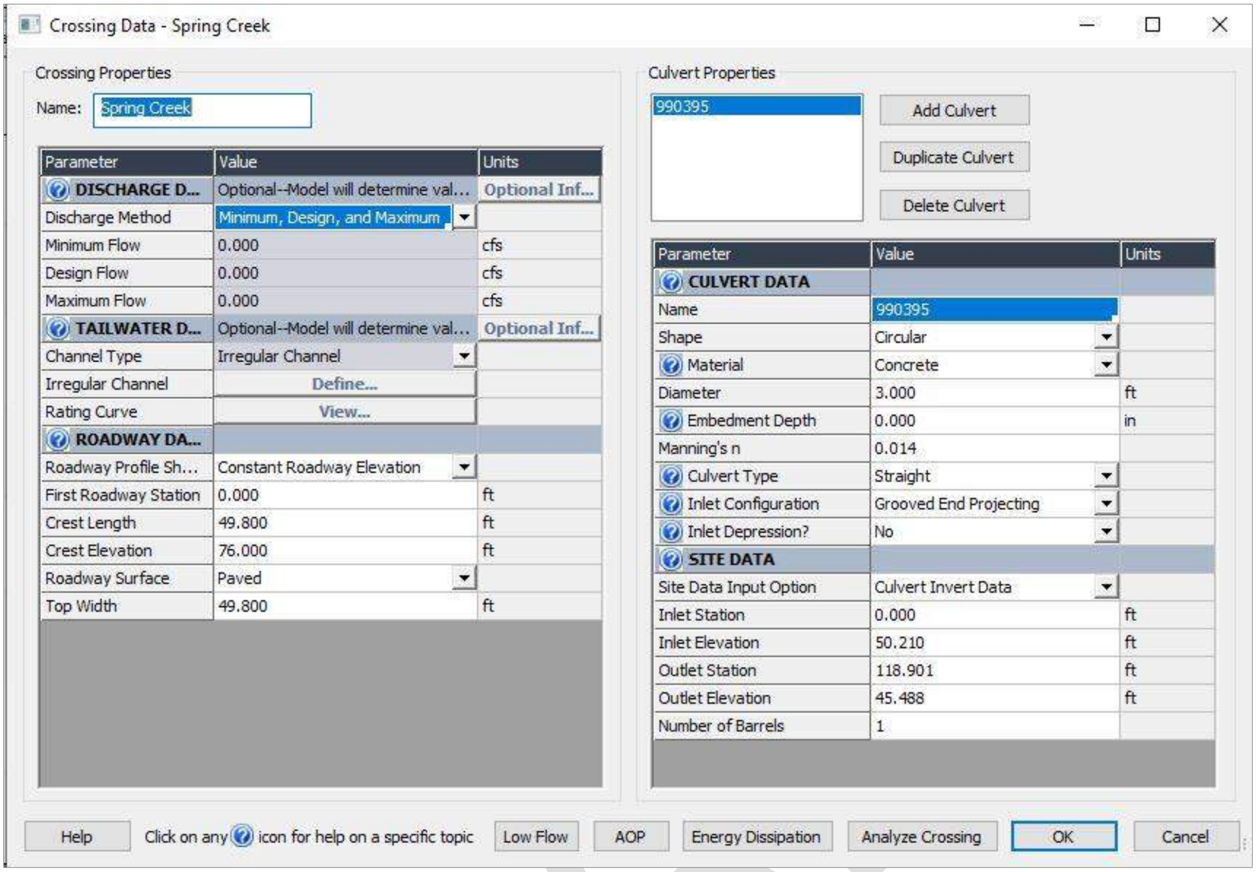

Figure 39: HY-8 culvert parameters

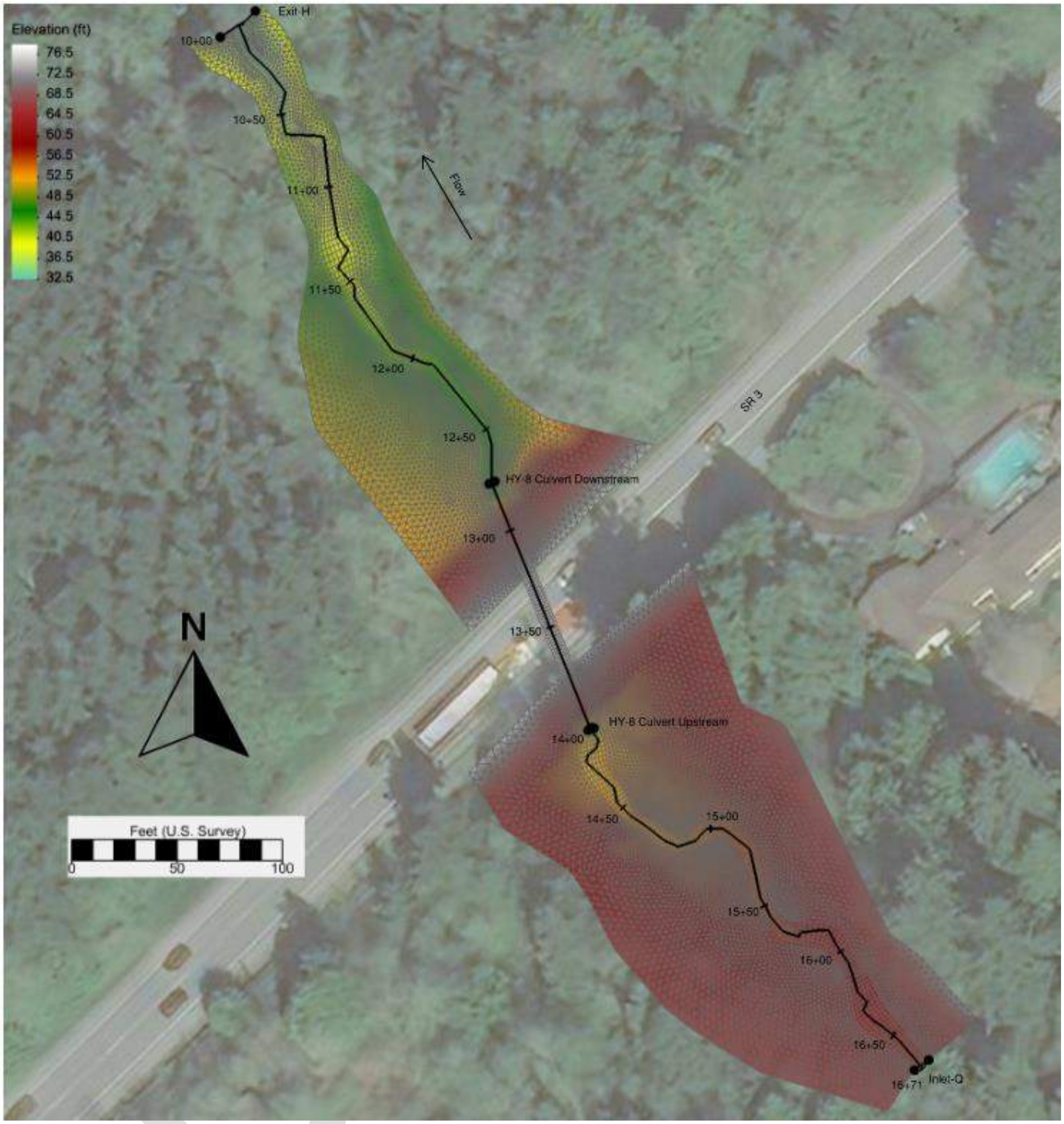

Figure 40: Existing-conditions boundary conditions

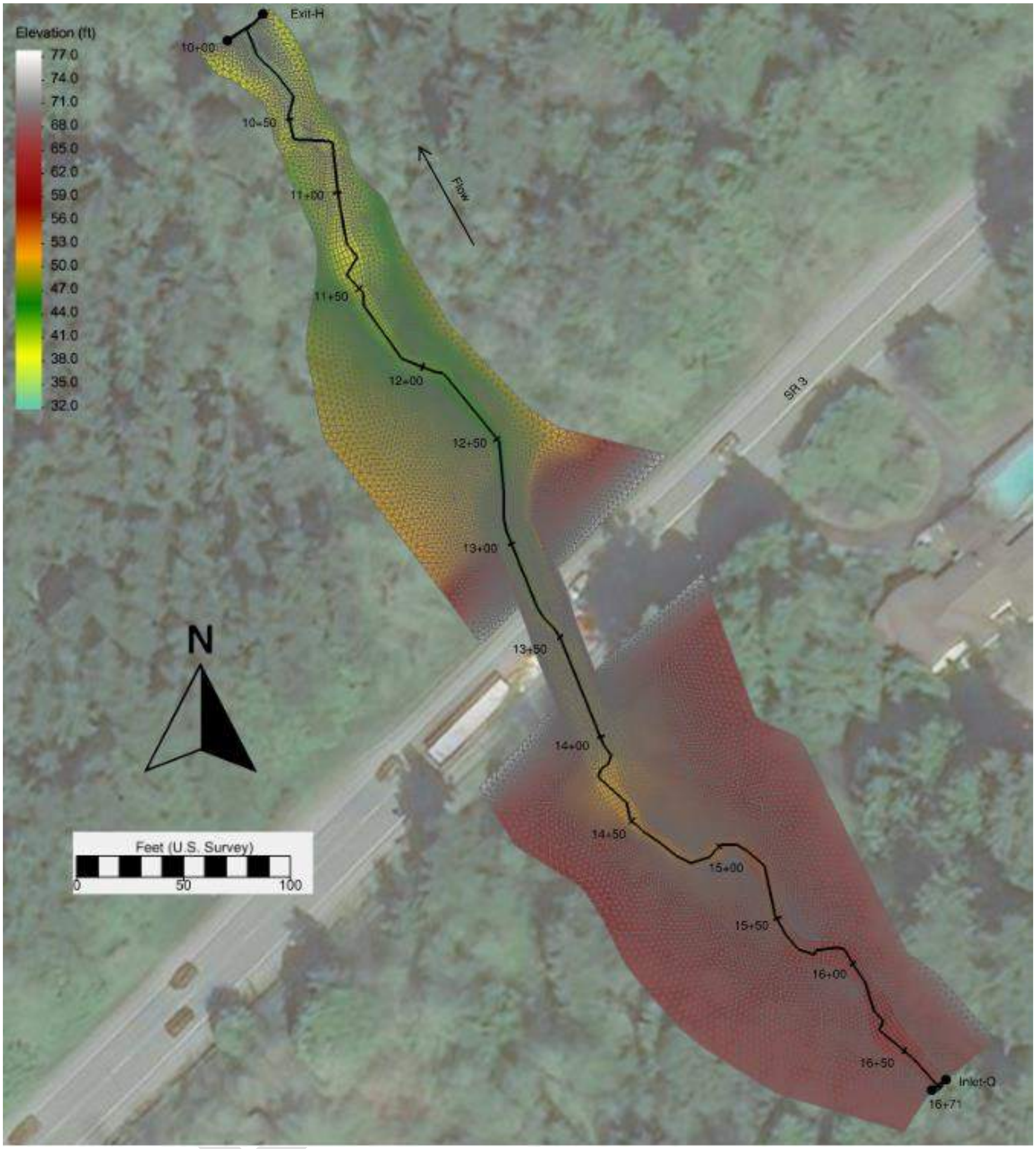

Figure 41: Proposed-conditions boundary conditions

5.1.5 Model Run Controls

For the 2-year event, the existing and proposed conditions were run for 3 hours with a time step of 0.5 second, and the model domain reached a stable steady-state condition after approximately 0.2 hour. For all other modeled events, the existing and proposed conditions were run for 5 hours, including 3 hours of ramp-up time, with a time step of 0.25 second. These simulations reached a stable steady-state condition after approximately 3.2 hours. This ramp-up time is included for the sake of model stability. For all modeled events, the initial condition is dry, the turbulence model is parabolic with a parabolic turbulence value of 0.7, and the output frequency is set at 5 minutes. Appendix I contains additional information regarding model stability.

5.1.6 Model Assumptions and Limitations

The hydraulic model is limited by the quality, density, and accuracy of each data input and how the information is parameterized by the model. A few notable limitations of the hydraulic model are summarized below:

- The model is 2D in the x and y directions based on the spacing and orientation of the grid cells and the depth integrated, meaning vertical advection or diffusion of momentum is assumed to be negligible relative to the x and y directions. This is colloquially stated as the “shallow water” assumption and is valid in most fluvial environments.
- The model assumes constant flow resistance across flow depths and is limited to using Manning’s *n* to characterize resistance, which is independent from flow depth. At lower-flow depths, friction is higher relative to larger-flow depths. Flow resistance, particularly on the floodplain, also varies seasonally as deciduous trees and shrubs shed their leaves in winter.
- The model is fixed bed; all features are static. However, at flood stage, a fraction of the bed material is mobile and creates pools and gravel bars, resulting in dynamic channel morphology. As noted in Section 4.1.3, the proposed design includes boulder habitat features that will function as semi-deformable steps. The evolution of the bed is not captured in the model.
- All reported model outputs are main channel averages except for depth, which is a true maximum value. Main channel average values represent trends in the hydraulic results, which at this stage of design is preferred over discrete peak values that may lead to improper design, based on limited information.
- The hydraulic model does not account for infiltration loss or hyporheic inflow.

5.2 Existing Conditions

The existing-condition model was run for the 2-year, 100-year, and 500-year design events based on the selected design flows, as described in Section 3. The respective cross section locations for reporting are shown on Figure 42. These sections were drawn at the approximate locations where BFWs were measured in the field, with the exception of the section at STA 11+80, which was an additional section drawn at the beginning of the reference reach. The average hydraulic results for WSE, velocity, and shear stress are reported in Table 15, along with maximum depth at each cross section.

The 2-year event WSE does not exceed bankfull and measured BFWs in the reference reach or elsewhere in the model domain. This may indicate that either the channel is incised and unable to access the floodplain at the 2-year event or that the calculated 2-year peak flow rate is an underestimate of the effective discharge. Jacobs discussed these results with WSDOT, and the guidance was given to proceed with the calculated 2-year peak flow rate rather than adjusting the hydrologic or hydraulic methods. In the reference reach, average velocities are 2 to 3 feet per second (fps) and maximum depths are less than 1 foot during the 2-year event.

The existing culvert is undersized for the 100-year and 500-year events and creates a submerged (pressure flow) culvert condition with headwater elevation of roughly 0.1 and 0.2 feet above the top of pipe, for each respective event. The backwater extends roughly 45 feet upstream for both events (Figure 43), and high velocities are present at the culvert outlet. In the reference reach, average velocities are 5 to 6 fps and maximum depths are less than 2 feet during the 100-year event. Upstream of the existing culvert where the channel is wide and shallow and banklines are poorly defined, the creek spreads out and slows in the floodplain during the 100-year and 500-year events. Elsewhere in the model domain, flow is relatively confined.

Figure 44 shows a typical section from the reference reach at STA 11+80 for the scenarios that were evaluated. Figure 45 shows the upstream and downstream 100-year velocity in plan view, and average cross section values are included in Table 16. SR 3 does not overtop under the 2-year, 100-year, or 500-year events. Additional existing-conditions model results are included in Appendix H.

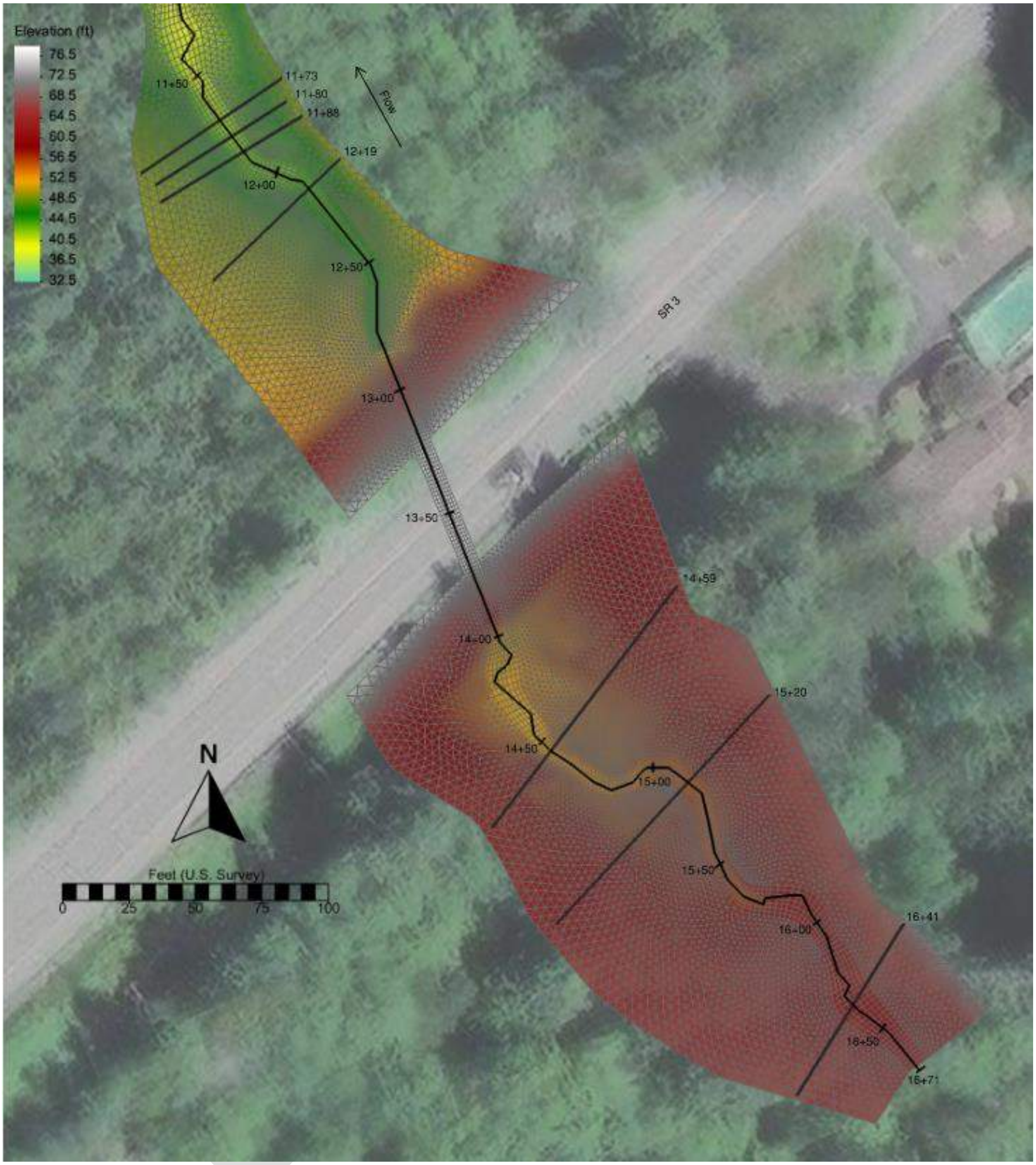

Figure 42: Locations of cross sections used for results reporting

Table 15: Average main channel hydraulic results for existing conditions[a]

Hydraulic parameter	Cross section	2-year	100-year	500-year
Average WSE (ft)	STA 11+73	42.3	43.1	43.1
	STA 11+80	42.8	43.5	43.5
	STA 11+88	43.0	43.9	44.0
	STA 12+19	44.4	45.1	45.1
	Structure STA 13+61	N/A	N/A	N/A
	STA 14+59	53.3	54.4	54.4
	STA 15+20	56.3	57.0	57.1
	STA 16+41	60.5	61.0	61.0
Max depth (ft)	STA 11+73	0.6	1.3	1.3
	STA 11+80	0.6	1.3	1.3
	STA 11+88	0.6	1.5	1.6
	STA 12+19	0.5	1.3	1.3
	Structure STA 13+61	N/A	N/A	N/A
	STA 14+59	0.6	1.6	1.7
	STA 15+20	0.6	1.4	1.4
	STA 16+41	0.4	1.0	1.0
Average velocity (fps)	STA 11+73	2.8	6	6.0
	STA 11+80	2.7	5.8	5.9
	STA 11+88	2.6	5.3	5.3
	STA 12+19	2.5	5.6	5.7
	Structure STA 13+61	N/A	N/A	N/A
	STA 14+59	3.2	6.5	6.6
	STA 15+20	2.3	4.7	4.7
	STA 16+41	2.4	4.2	4.3
Average shear (lb/SF)	STA 11+73	1.2	2.5	2.5
	STA 11+80	0.9	2.3	2.3
	STA 11+88	0.9	1.9	1.9
	STA 12+19	0.9	2.2	2.2
	Structure STA 13+61	N/A	N/A	N/A
	STA 14+59	1.7	2.9	3.0
	STA 15+20	0.6	1.5	1.5
	STA 16+41	0.8	1.6	1.6

a. Main channel extents were approximated by 2-year event modeled water surface top widths.

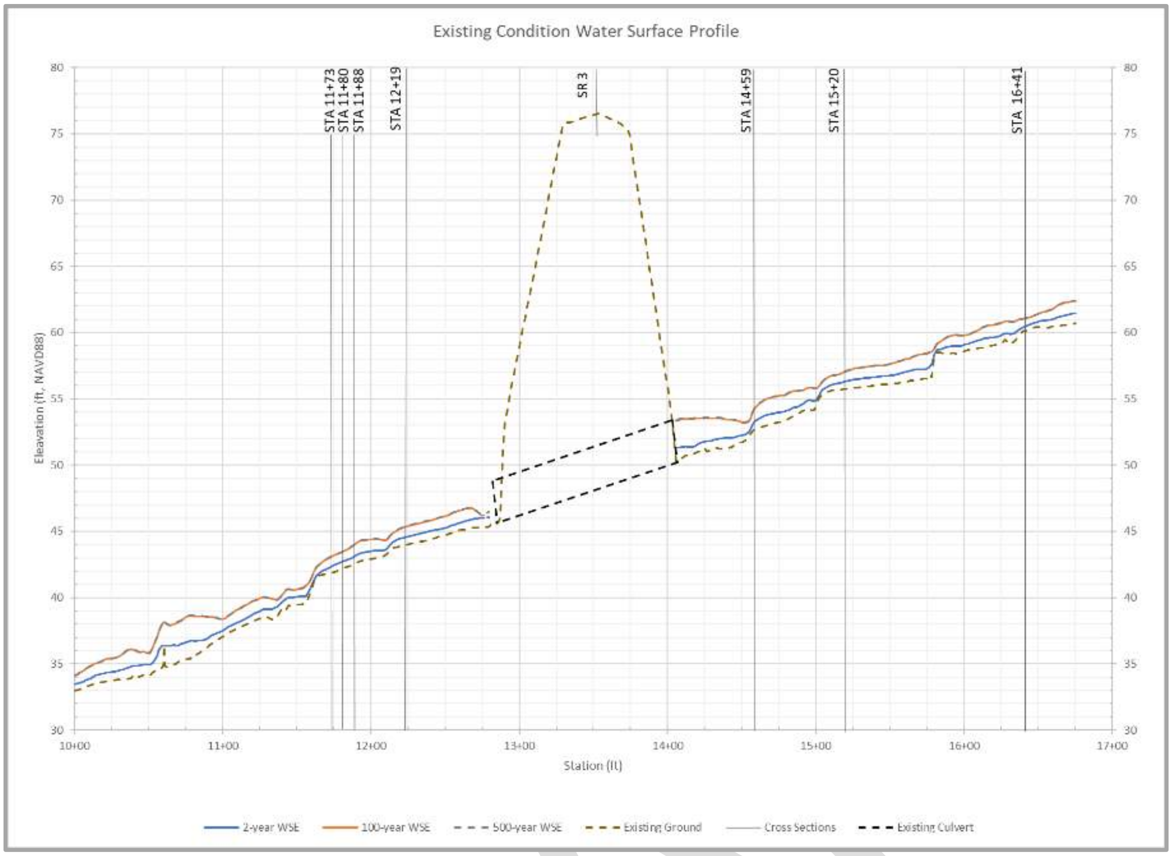

Figure 43: Existing-conditions water surface profiles

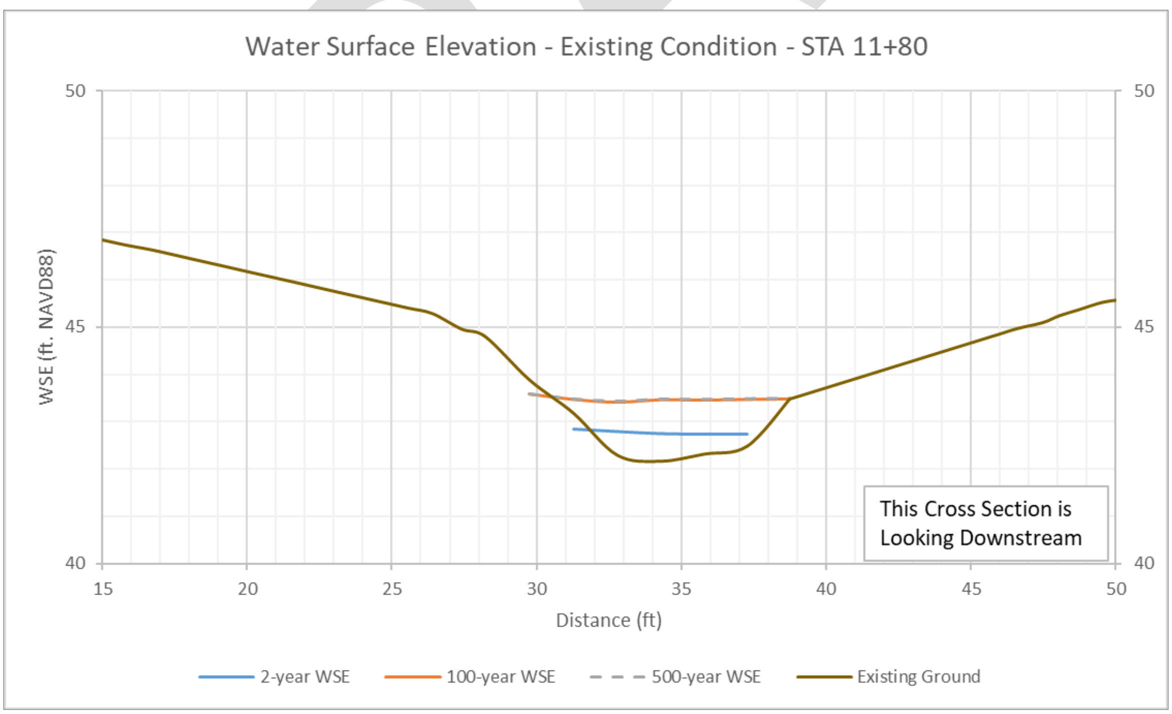

Figure 44: Typical downstream existing channel (reference reach) cross section (STA 11+80)

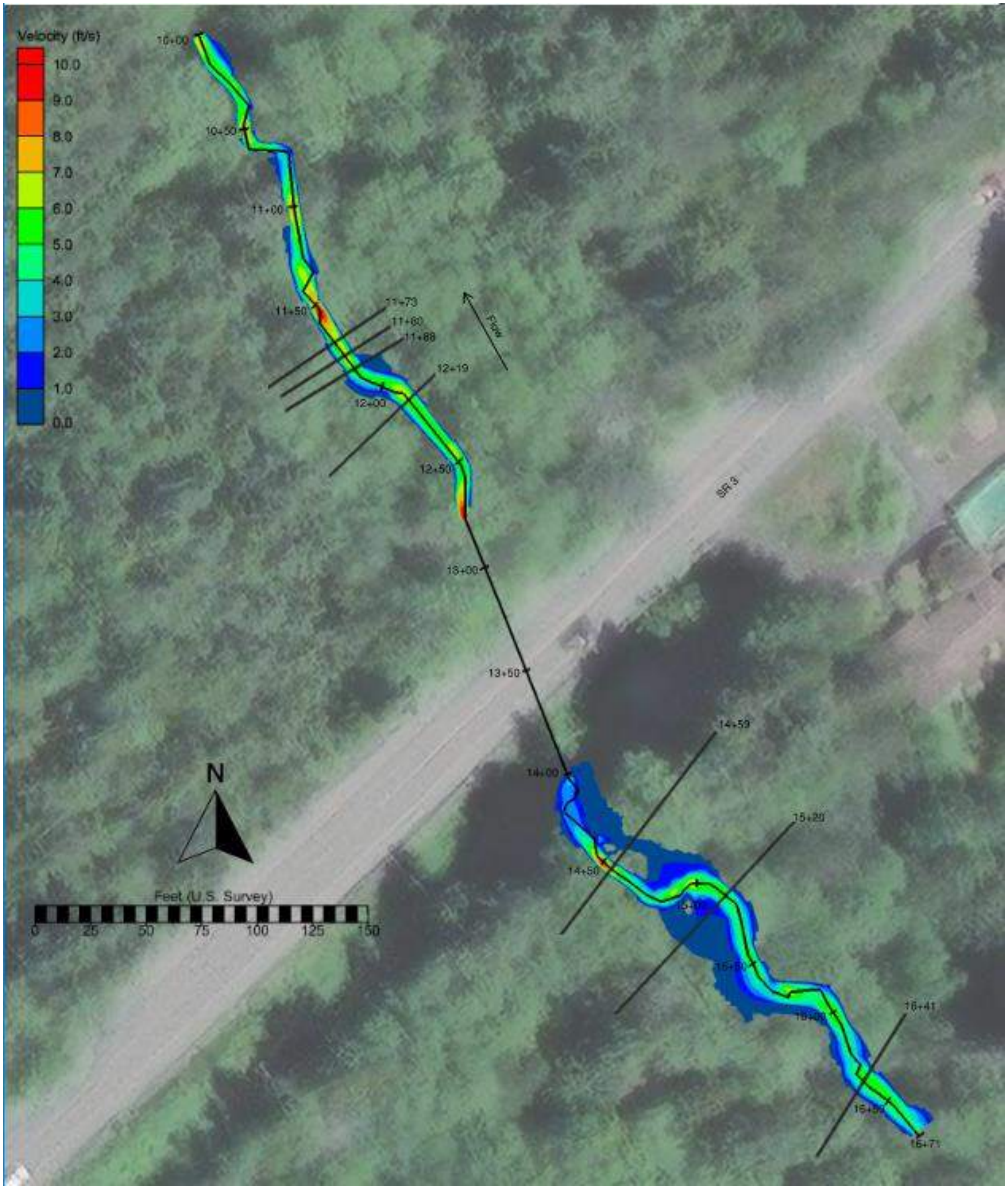

Figure 45: Existing-conditions 100-year velocity map with cross section locations

Table 16: Existing-conditions average channel and floodplains velocities

Cross section location	Q100 average velocities (fps)		
	LOB[a]	Main channel	ROB[a]
STA 11+73	1.9	6.0	2.8
STA 11+80	2.0	5.8	2.6
STA 11+88	2.0	5.3	0.7
STA 12+19	1.9	5.6	2.4
Structure STA 13+61	N/A	N/A	N/A
STA 14+59	3.8	6.5	0.7
STA 15+20	1.0	4.7	2.2
STA 16+41	1.5	4.2	NA

a. Right overbank (ROB) and left overbank (LOB) locations were approximated by 2-year event modeled water surface top widths.

5.3 Natural Conditions

A natural conditions model was not required as the system is confined, as noted in Section 2.7.2.1.

5.4 Proposed Conditions: 18-foot Minimum Hydraulic Width

The hydraulic width is defined as the width perpendicular to the creek beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic modeling assumes vertical walls at the edge of the minimum hydraulic width unless otherwise specified. See Section 4.2.2 for a description of how the minimum hydraulic width was determined. An 18-foot minimum hydraulic width opening was determined to be appropriate to provide adequate flood conveyance capacity, sediment transport capacity from upstream reaches, buffer between channel edge and structure wall/cut slope at meanders, and width to pass LWM.

The proposed-condition model was run for the 2-year, 100-year, 500-year, and projected 2080, 100-year events based on the selected design flows, as described in Section 3. The respective cross section locations for reporting are shown on Figure 46. The average hydraulic results for WSE, velocity, and shear stress are reported in Table 17, along with the maximum depth at each cross section.

The proposed 18-foot structure was modeled with a graded, slightly meandering channel and roughness defined for the channel and floodplain within the structure. The proposed habitat boulders, SWM, steps, treads, and low-flow channel discussed in Section 4.1.1 were not discretely modeled but were represented as a relative roughness region. Further modeling refinement will be required at future stages of the design.

The proposed channel performs similarly to the reference reach with regard to the average channel velocity and the velocity distribution. Model results indicate an average velocity of 5.3 fps in the structure during the 100-year event, similar to the reference reach range of 4.2 to 5.8 fps. Other hydraulic metrics at STA 13+61 (Figure 46, Figure 47, and Figure 48), shown in

Table 17, are within the range of observed values downstream in the reference reach at STA 11+80 and upstream at STA 16+41. The spatial distribution of upstream and downstream velocity at the 100-year event is shown in plan view on Figure 49 and tabulated in Table 18. Additional existing and proposed-conditions model results are in Appendix H. Within the proposed structure, the 2-year flow is contained within the channel banks similar to the existing conditions in the reference reach, but the 100-year and 500-year flows spread out into the floodplain more than in the existing conditions in the reference reach (Figure 44 and Figure 48). This difference is due to the possible channel incision in the existing reference reach, as noted in Section 5.2. The entire project reach is incised into the valley floor but typically exhibits an inset floodplain on one or both sides of the channel. Additionally, the project reach does not exhibit evidence of active incision.

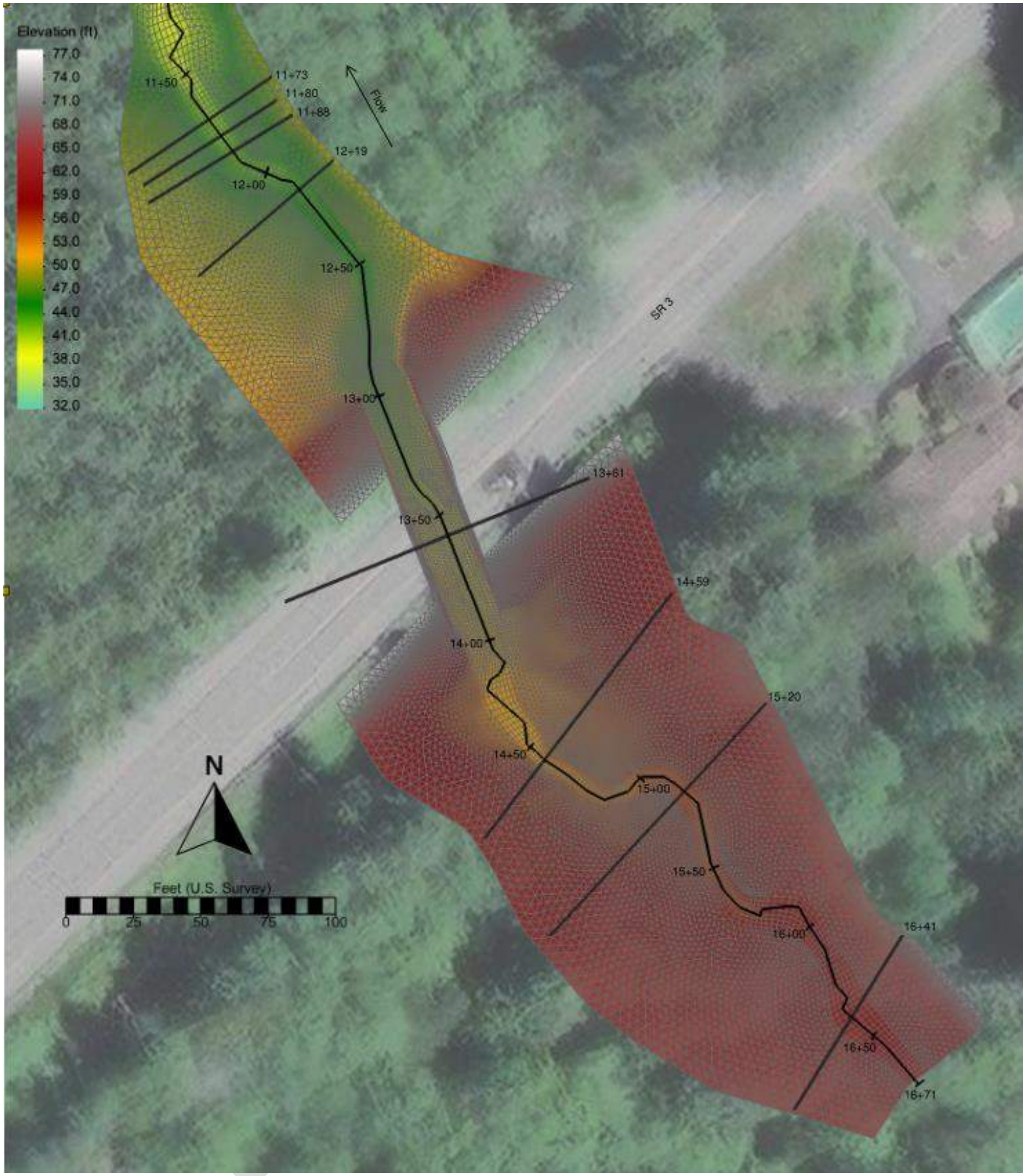

Figure 46: Locations of cross sections on proposed alignment used for results reporting

Table 17: Average main channel hydraulic results for proposed conditions

Hydraulic parameter	Cross section	2-year	100-year	Projected 2080, 100-Year	500-year
Average WSE (ft)	STA 11+73	42.3	43.1	43.4	43.1
	STA 11+80	42.8	43.6	43.9	43.6
	STA 11+88	43.2	44.1	44.4	44.1
	STA 12+19	44.5	45.5	45.8	45.5
	Structure 13+61	49.1	49.8	50.0	49.8
	STA 14+59	53.4	54.5	54.7	54.5
	STA 15+20	56.5	57.4	57.6	57.4
	STA 16+41	60.3	60.9	61.1	60.9
Max depth (ft)	STA 11+73	0.6	1.4	1.6	1.4
	STA 11+80	0.6	1.4	1.8	1.5
	STA 11+88	0.7	1.6	1.9	1.6
	STA 12+19	0.6	1.7	2.0	1.7
	Structure STA 13+61	0.6	1.3	1.5	1.3
	STA 14+59	0.7	1.8	1.9	1.8
	STA 15+20	0.8	1.7	2.0	1.7
	STA 16+41	0.6	1.2	1.4	1.2
Average velocity (fps)	STA 11+73	2.8	5.8	6.5	5.9
	STA 11+80	2.6	5.2	5.6	5.2
	STA 11+88	2.6	4.2	4.3	4.2
	STA 12+19	2.2	4.0	4.2	4.0
	Structure STA 13+61	2.6	5.3	5.8	5.4
	STA 14+59	2.6	4.9	5.3	5.0
	STA 15+20	1.6	3.3	3.7	3.4
	STA 16+41	2.4	4.5	5.2	4.5
Average shear (lb/SF)	STA 11+73	1.2	2.4	2.7	2.4
	STA 11+80	0.9	1.8	2.0	1.8
	STA 11+88	1.6	3.6	3.8	3.6
	STA 12+19	0.6	1.0	1.0	1.0
	Structure STA 13+61	0.9	2.2	2.6	2.3
	STA 14+59	3.1	8.5	9.7	8.6
	STA 15+20	0.3	1.1	1.3	1.1
	STA 16+41	1.0	1.8	2.1	1.8

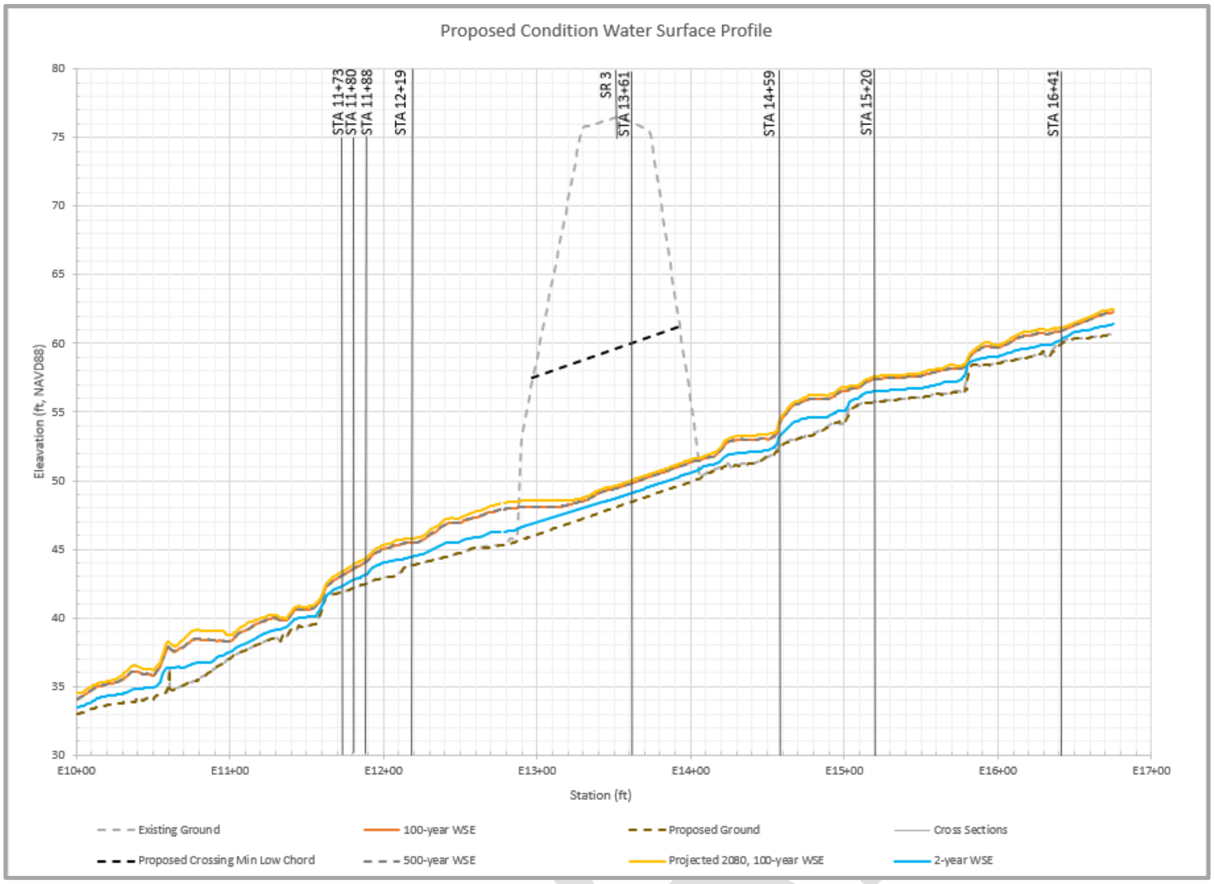

Figure 47: Proposed-conditions water surface profiles

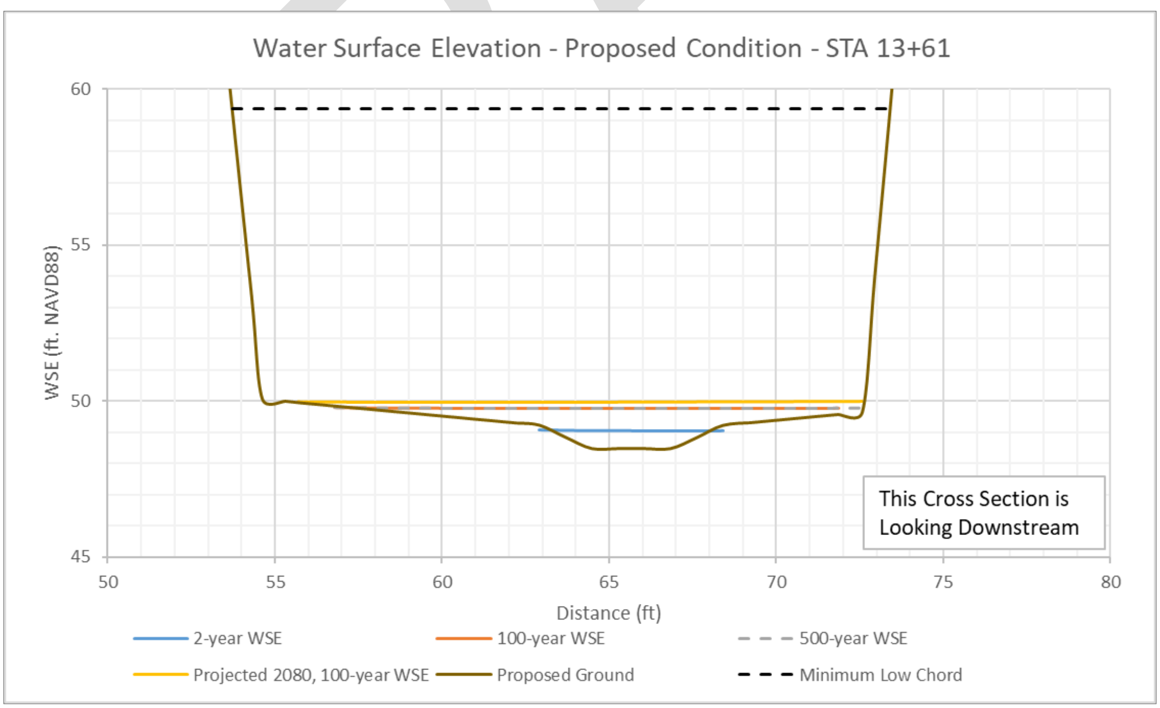

Figure 48: Typical section through proposed structure (STA 13+61)

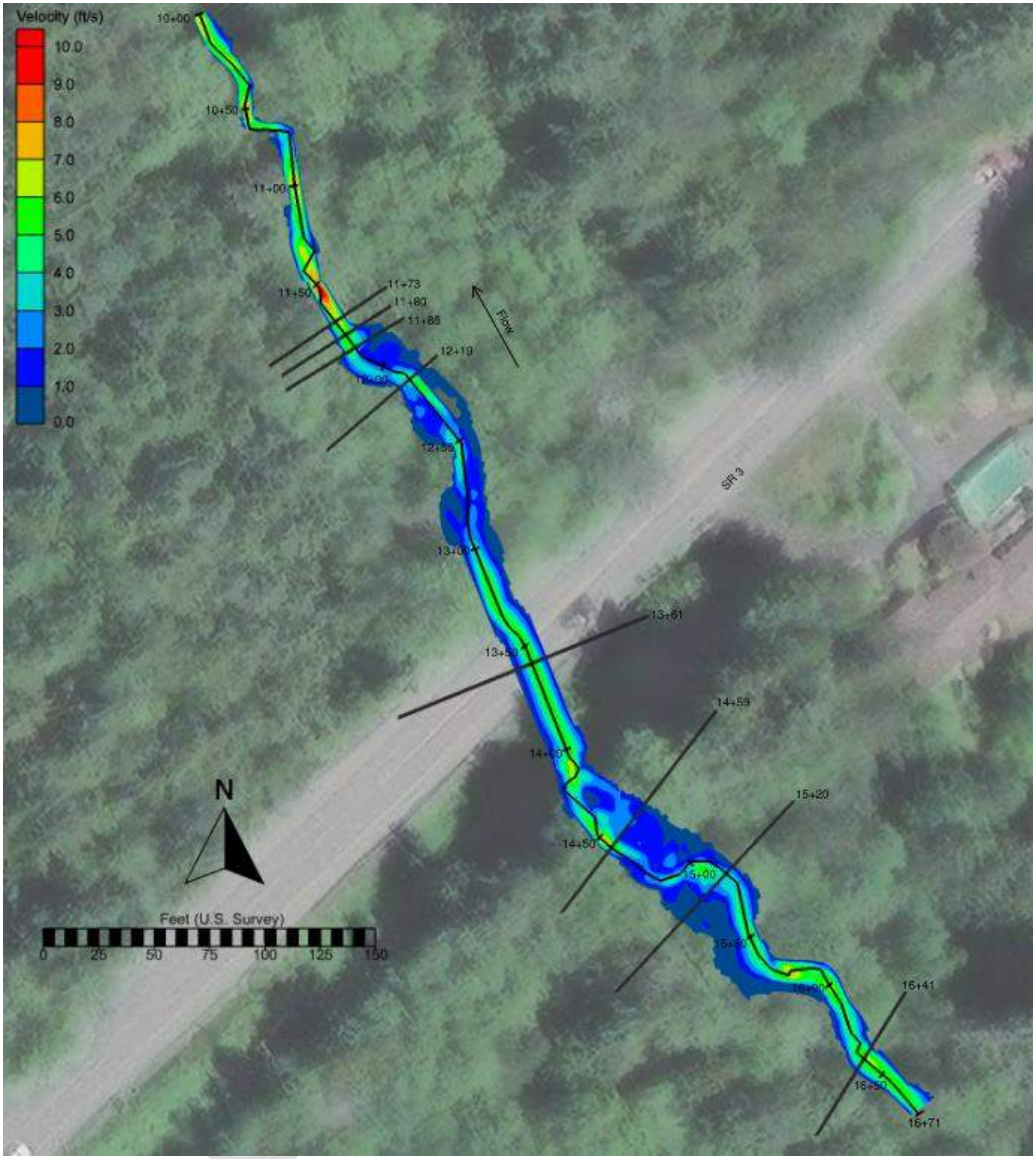

Figure 49: Proposed-conditions 100-year velocity map

Table 18: Proposed-conditions average channel and floodplains velocities

Cross section location	Q100 average velocities (fps)			2080 Q100 average velocity (fps)		
	LOB[a]	Main channel	ROB[a]	LOB[a]	Main channel	ROB[a]
STA 11+73	2.0	5.8	2.8	2.4	6.5	3.5
STA 11+80	1.5	5.2	2.0	2.8	5.6	2.0
STA 11+88	2.7	4.2	1.4	2.4	4.3	1.4
STA 12+19	2.2	4.0	1.6	2.5	4.2	1.6
Structure 13+61	2.0	5.3	2.6	2.7	5.8	3.4
STA 14+59	1.9	4.9	1.9	2.3	5.3	2.7
STA 15+20	1.4	3.3	1.0	1.9	3.7	1.2
STA 16+41	1.5	4.50	NA	1.5	5.2	0.4

a. ROB/LOB locations were approximated by 2-year event water surface top widths.

6 Floodplain Evaluation

This project is not within a FEMA special flood hazard area but rather in a Zone X area of minimal flood hazard (FEMA 2017); see Appendix A for FIRMette. The existing project and expected proposed project conditions were evaluated to determine whether the project would cause a change in flood risk.

6.1 Water Surface Elevations

Generally, WSEs decrease across the model domain when comparing the existing and proposed conditions. Figure 50 shows the water surface profile, comparing the 100-year mean recurrence interval results for existing and proposed conditions, and Figure 51 shows the change in WSE between the existing and proposed conditions in plan view. There are small, localized areas where WSEs are anticipated to increase, particularly in the vicinity of the proposed LWM. This water surface rise is less than 1 foot and is limited to the reach that extends from 100 feet downstream of the SR 3 crossing to 150 feet upstream. The changes in WSE and inundation areas do not pose a risk to properties or infrastructure. A flood risk assessment will be developed during later stages of the design.

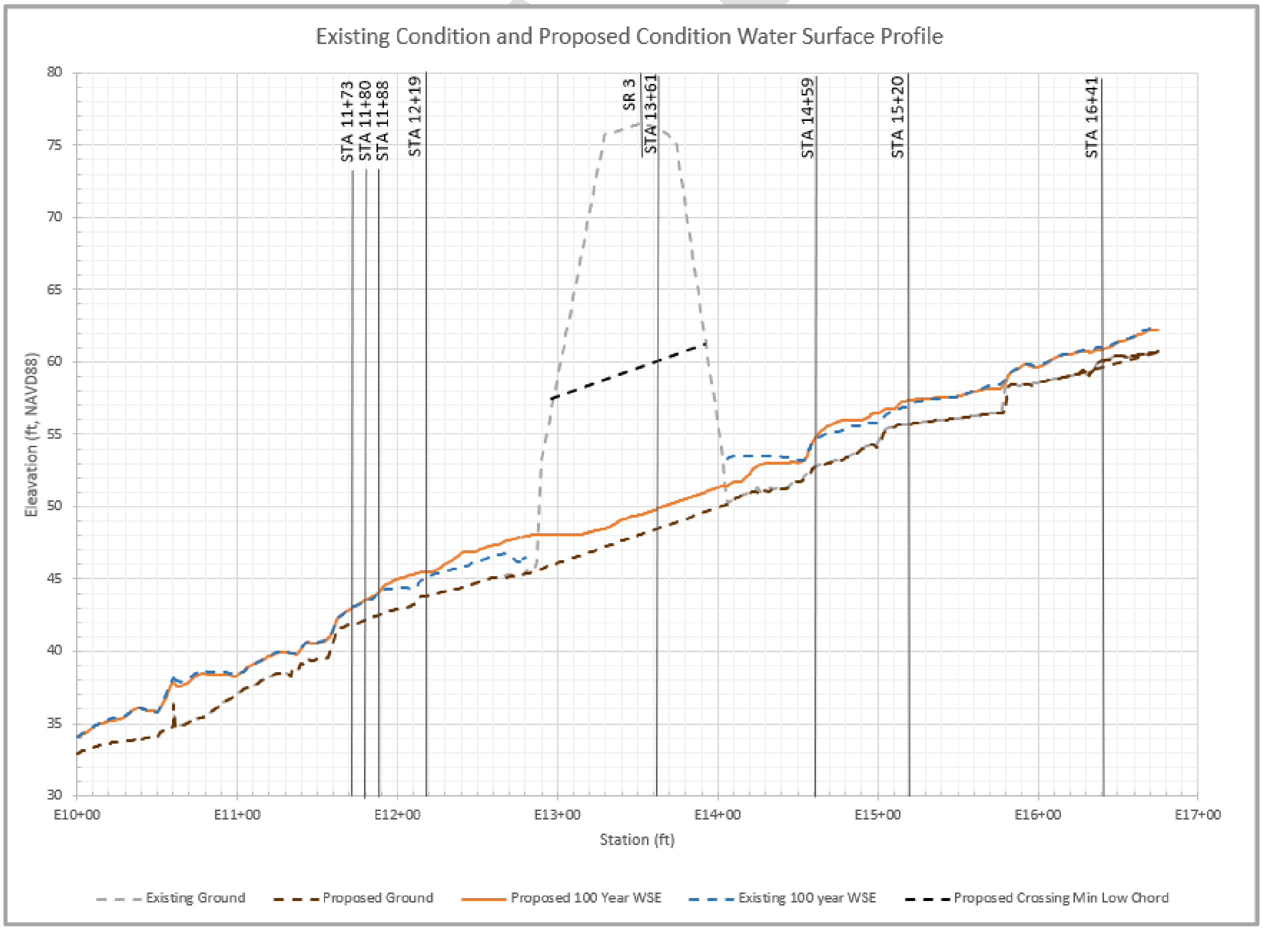

Figure 50: Existing- and proposed-conditions 100-year water surface profile comparison

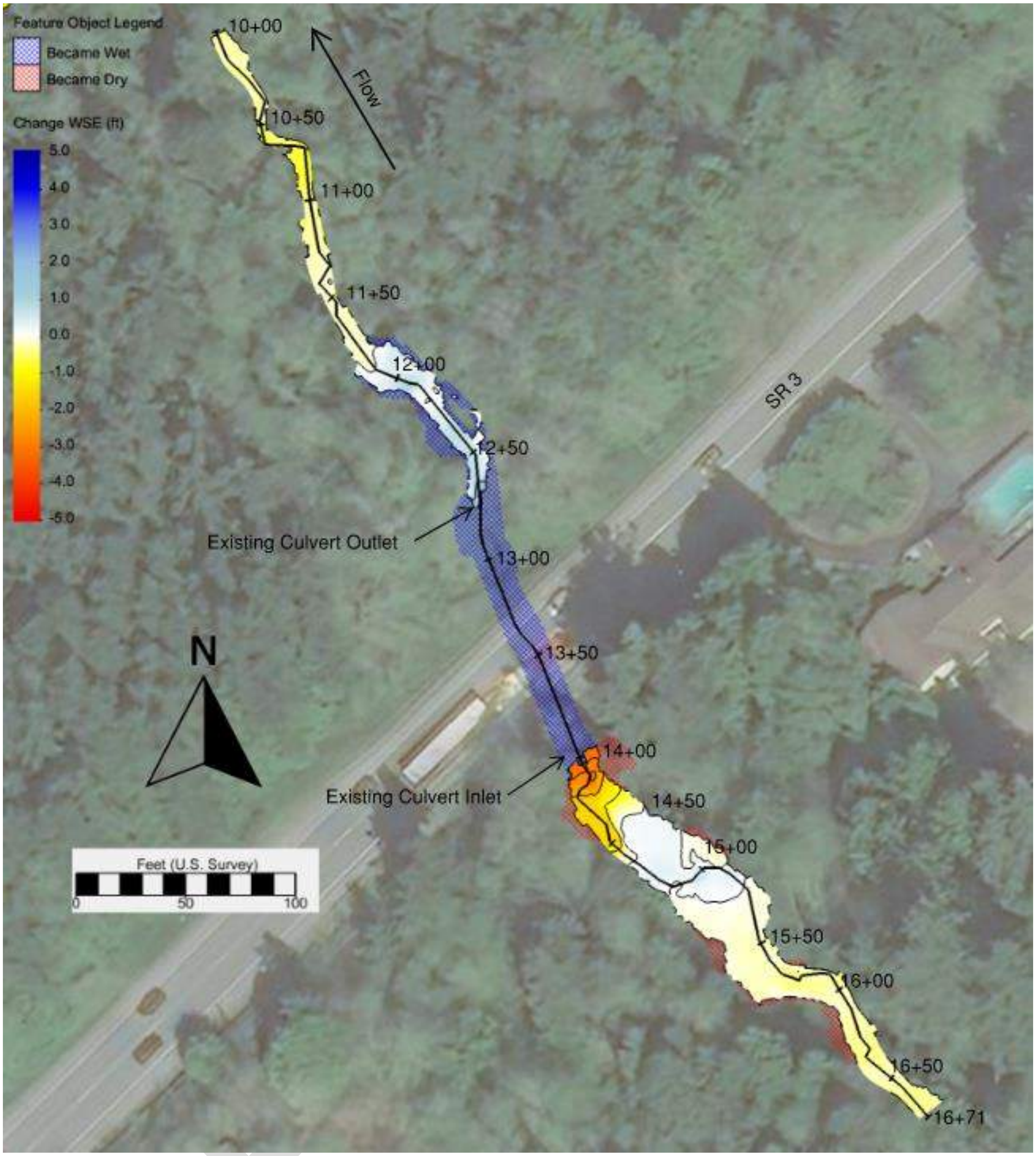

Figure 51: 100-year WSE change from existing to proposed

Scour is still on its own review cycle and should not be reviewed in Draft 2. Scour will be reincorporated at Draft 3 / External

7 Preliminary Scour Analysis

For this preliminary phase of the project, the risk for lateral migration, potential for long-term degradation and evaluation of preliminary total scour is based on available data, including but not limited to the geotechnical scoping memorandum, Wolman pebble counts (Section 2.7.4), and proposed channel design concept (Appendix C). This evaluation is to be considered preliminary and is not to be taken as a final recommendation.

Using the results of the hydraulic analysis (Section 5.4), based on the recommended minimum hydraulic opening, and considering the potential for lateral channel migration, preliminary scour calculations for the scour design flood and scour check flood were performed following the procedures outlined in *Evaluating Scour at Bridges* (HEC-18) (Arneson et al. 2012). For this analysis, the scour design flood is considered the event that produces the greatest depth of scour, the 100-year event. The scour check flood, as defined by WSDOT's *Hydraulics Manual* is considered equivalent or larger than the design event, and is defined as the 2080, 100-year discharge. Additionally, the 2-year, 10-year, and 500-year events were analyzed to investigate how the full spectrum of flood discharges influence scour at the site, and an additional approach cross section location was analyzed to determine the sensitivity of the scour results to this input.

Scour components considered in the analysis include the following:

- Long-term degradation
- Contraction scour
- Local scour

In addition to the three scour components listed above, the potential for lateral migration was assessed to evaluate total scour at the proposed highway infrastructure. These various scour components will be discussed in the following sections.

7.1 Lateral Migration

The risk of lateral migration is moderate. Two factors create a moderate risk of channel migration: (1) a relatively high sediment load, and, a channel-spanning blockage could accumulate sediment and force the channel to migrate around it, and (2) geotechnical data indicates relatively erodible materials that would have low resistance to channel migration (WSDOT 2022c). These factors are attenuated by resistance to incision by extensive mature vegetation in the floodplain.

7.2 Long-term Degradation of the Channel Bed

The watershed longitudinal profile (Figure 52) is relatively straight near the SR 3 crossing, indicating neither excess deposition nor erosion, and the projected slope (or equilibrium profile) is functionally the same as the existing profile, indicating neither aggradation nor degradation are likely. Gradient decreases significantly as the Creek approaches base-level control approximately 1,400 feet downstream of the SR 3 crossing, where it flows into the Hood Canal.

As noted in Section 2.7.4, small, vertical steps are formed at finer spatial scales by accumulations of wood, roots, and boulders in the channel. These steps function as minor grade control structures, but the longevity of these steps is relatively short. One such step is present approximately 125 feet downstream of the crossing. If the downstream step degrades, it could initiate a headcut, regrading the channel upstream through the crossing. With an equilibrium slope of roughly 4 percent, the profile may degrade up to 1.5 feet. Geotechnical data do not indicate any competent bedrock or non-erodible material at a depth shallower than this estimate.

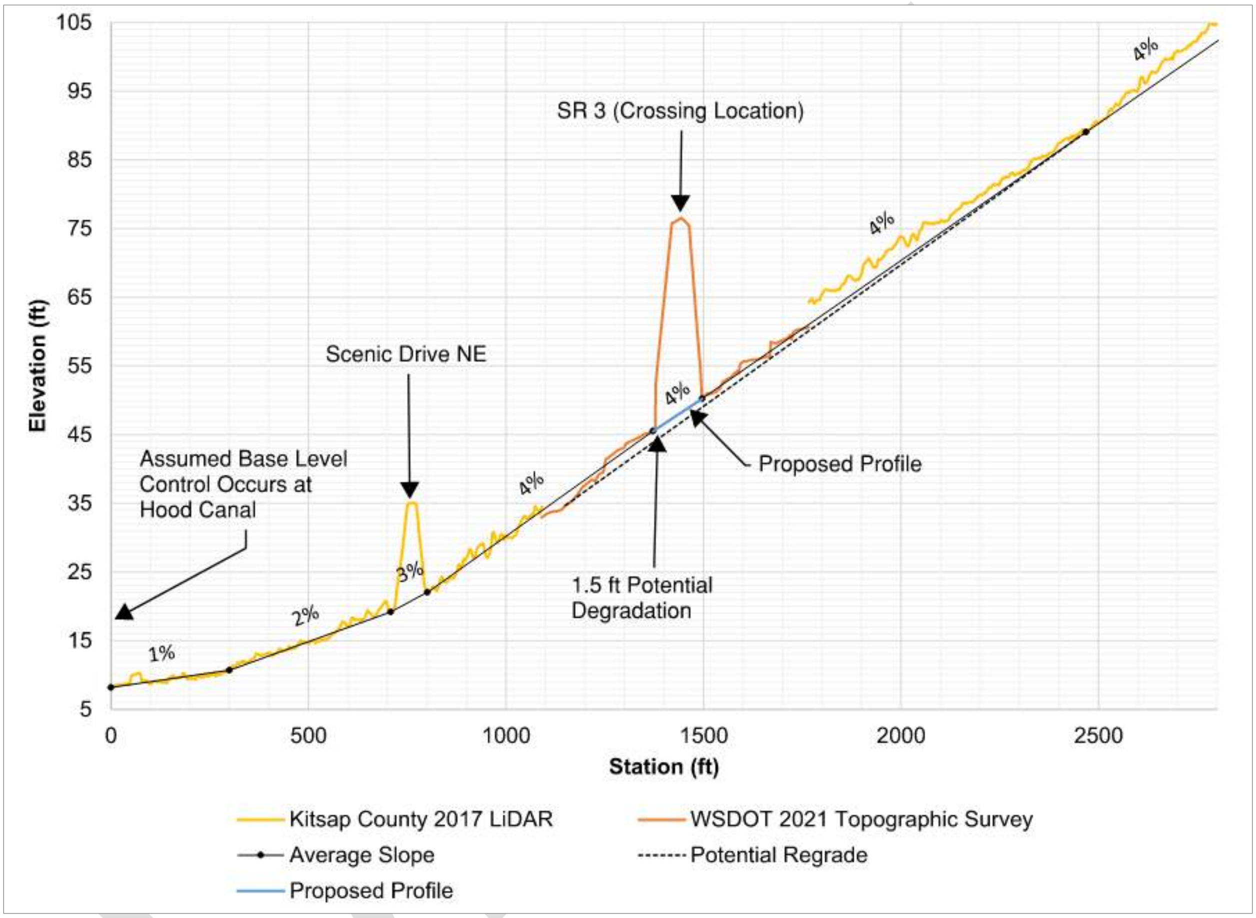

Figure 52: Potential long-term degradation at the proposed structure

A quantitative assessment of long-term degradation following guidance in HEC-20 (Lagasse et al. 2012) or HDS 7 (Zevenbergen et al. 2012) was not performed because no evidence of the system being supply-limited was observed. A maximum of 1.5 feet of potential long-term degradation will be carried forward as a design recommendation.

7.3 Contraction Scour

Contraction scour was evaluated through the culvert and computed following guidance from HEC-18 (Arneson et al. 2012). Based on the geometry of the crossing and potential for lateral migration, contraction scour was computed for the main channel condition only. The particle diameters used in the clear-water equation are based on the average of the surface pebble counts collected in the field (Table 5, Section 2.7.3), including a D_{50} of 0.5 inches. The approach arc was drawn at the closest distance upstream of the crossing outside of the influence of the crossing, channel bends, and proposed LWM. The width transporting sediment for both the approach and contracted sections are defined based on the surveyed bank lines and the Critical Velocity Index (CVI) map (Figure 53). CVI results indicate that live-bed conditions exist upstream and within the structure during all discharges analyzed.

Following HEC-18 guidance for live-bed conditions, both live-bed and clear-water contraction scour were calculated, and the lower of the two values recommended. The main channel contraction scour results in 0.2 feet of predicted scour for both the design and check flood events (Figure 54).

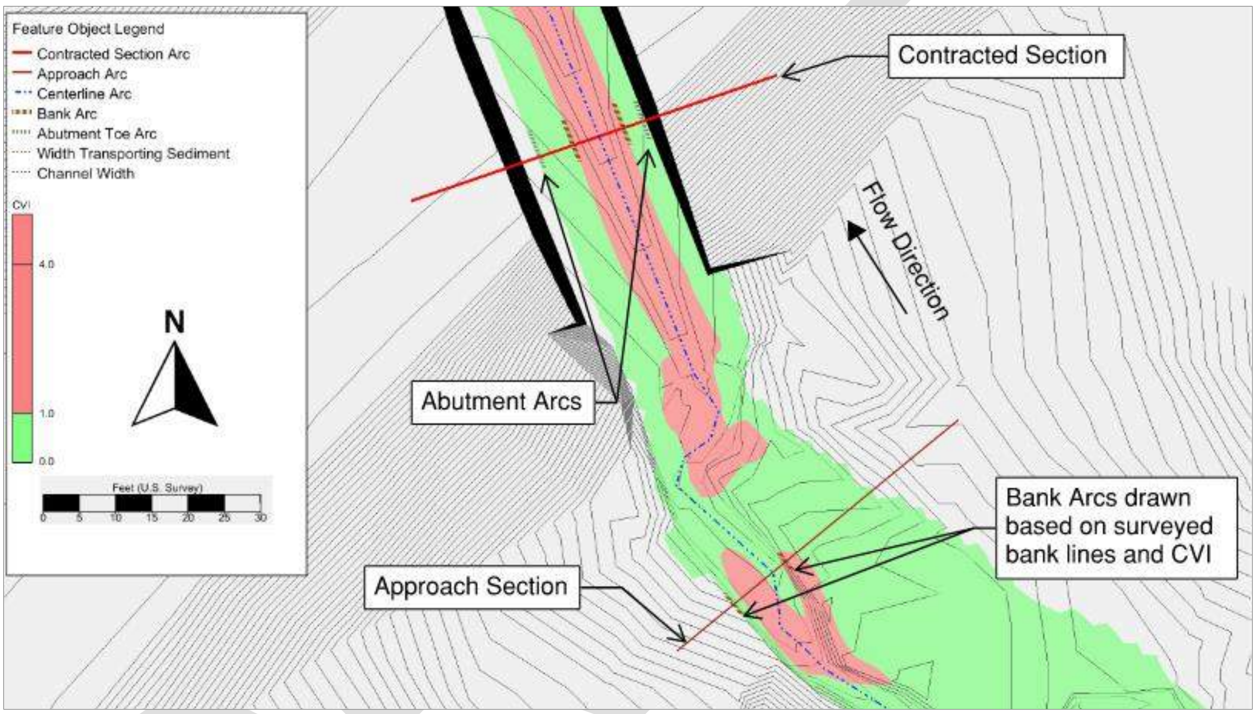

Figure 53: Location of bridge scour coverage arcs during scour design event

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.14	ft	
D50	12.700000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	3.69	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	3.96	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	36.06	cfs	
Bottom Width in Contracted Section	7.20	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	0.97	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.038201	ft/ft	
Discharge in Contracted Section	36.06	cfs	
Discharge Upstream that is Transporting Sediment	39.18	cfs	
Width in Contracted Section	7.20	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	9.28	ft	
Depth Prior to Scour in Contracted Section	0.97	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	15.875000	mm	
Average Depth in Contracted Section after Scour	1.15	ft	
Scour Depth	0.18	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.19	ft/s	
Fall Velocity	1.58	ft/s	
Average Depth in Contracted Section after Scour	1.25	ft	
Scour Depth	0.28	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.1947	lb/ft^2	
Shear Required for Movement of D50 Particle	0.1667	lb/ft^2	
Recommendations			
Recommended Scour Depth	0.18	ft	Negative values imply 'zero' ...

Figure 54: Results for main channel live-bed and clear-water contraction scour for the design event

7.4 Local Scour

7.4.1 Pier Scour

The crossing will not have piers and therefore pier scour was not calculated.

7.4.2 Abutment Scour

Abutment scour was estimated using the National Cooperative Highway Research Program (NCHRP) 24-20 approach for the scour design flood and scour check flood (Ettema et al. 2010). Based on the geometry of the crossing and potential for lateral migration, scour condition A (main channel hydraulics) was considered applicable for all flows examined. The NCHRP equation applies an amplification factor to contraction scour in order to account for the effects of large-scale turbulence of scour along an abutment. NCHRP 24-20 calculates a maximum flow depth including abutment scour at the abutment, and scour depth was referenced as a depth below the thalweg by adjusting the flow depth prior to scour to the thalweg depth. Left and right bank abutment scour was analyzed, resulting in a maximum of 1.0 feet of scour predicted along both abutments for the design event and 0.4 feet of scour for the check flood event. The hydraulic toolbox results for abutment scour at the left abutment wall are shown on Figure 55.

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Live Bed		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutment		
Unit Discharge, Upstream in Main Channel (q1)	4.22	cfs/ft	
Unit Discharge in Constricted Area (q2)	5.00	cfs/ft	
D50	12.710160	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.14	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	1.32	ft	Depth at Abutment Toe
Results			
q2 / q1	1.18		
Average Velocity Upstream	3.69	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	3.96	ft/s	
Scour Condition	Live Bed		
Scour Condition	a (Main Channel)		
Amplification Factor	1.73		
Flow Depth including Contraction Scour	1.32	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.28	ft	Including the long-term scour de...
Scour Hole Depth	0.96	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	1.00	ft	

Figure 55: Hydraulic toolbox results for left bank abutment scour for the design event

7.4.3 Bend Scour

Bend scour was not quantified at this crossing given the lack of anticipated bends in the vicinity of the crossing.

7.5 Total Scour

Calculated total scour depths for the proposed Spring Creek to Hood Canal structure are provided in Table 19. Local abutment scour is not combined with contraction scour, rather the larger of the two is recommended. Total scour is estimated to be 2.5 feet during the 100-year event and 1.9 feet during the 2080, 100-year event. HQ Hydraulics Recommends that the structure be designed to account for the depths of scour provided in Table 19. No structure type has been recommended by HQ Hydraulics.

Table 19: Calculated scour analysis summary for SR 3 Spring Creek to Hood Canal

Scour Condition	Contracted Section of SR 3 Structure[a]	
	Design Flood Event 100-year	Check Flood Event 2080, 100-year
Long-Term Degradation (feet)	1.5	1.5
Contraction Scour (feet)	0.2	0.2
Local Abutment Scour (feet)	1.0	0.4
Total Depth of Scour (feet)[b]	**2.5**	**1.9**

a. Contracted section location is shown on Figure 53.
b. Depths do not include geotechnical requirements for any additional depth below the calculated scour.

To test the sensitivity of scour results to the placement of the upstream approach cross section, contraction scour and local scour were analyzed for the design event using a different upstream approach cross section location. The total scour results in this sensitivity analysis scenario were less than the results shown in Table 19, indicating that the reported results are conservative.

8 Scour Countermeasures

The need for scour countermeasures has not yet been determined. If scour countermeasures are needed, the structure free zone will be determined additional to the minimum hydraulic opening. The minimum hydraulic opening, as described in Section 4.2, is 18 feet. Figure 56 is a copy of Figure 7-8 from the WSDOT *Hydraulics Manual*, showing a conceptual layout if scour countermeasures are needed given the presence of abutment scour.

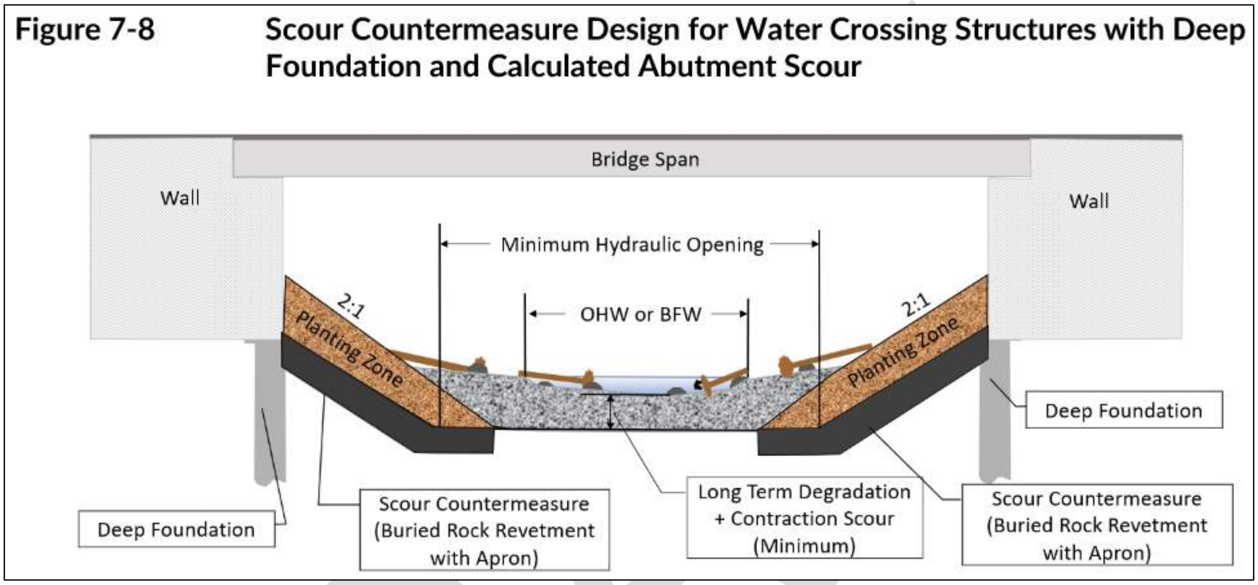

Figure 56: Conceptual diagram of scour countermeasures (WSDOT 2022b, 7-29)

9 Summary

Table 20 presents a summary of the results of this PHD report.

Table 20: Report summary

Stream crossing category	Element	Value	Report location
Habitat gain	Total length	4,728 LF	2.1 Site Description
Bankfull width	Reference reach found?	Yes	2.7.1 Reference Reach Selection
	Design BFW	5.5 ft	2.7.2 Channel Geometry
	Concurrence BFW	7.5 ft	2.7.2 Channel Geometry
Floodplain utilization ratio (FUR)	Flood-prone width	14 ft	2.7.2.1 Floodplain Utilization Ratio
	Average FUR	2.4 (US) – 1.9 (DS)	2.7.2.1 Floodplain Utilization Ratio
Channel morphology	Existing	Step/pool/tread	2.7.2 Channel Geometry
	Proposed	Step/pool/tread	4.3.2 Channel Complexity
Hydrology/design flows	100-yr flow	42 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100-yr flow	61 cfs	3 Hydrology and Peak Flow Estimates
	2080, 100 yr used for design	No	3 Hydrology and Peak Flow Estimates
	Dry channel in summer	No	3 Hydrology and Peak Flow Estimates
Channel geometry	Existing	See Section 2.7.2	2.7.2 Channel Geometry
	Proposed	See Section 4.1.1	4.1.1 Channel Planform and Shape
Channel slope/gradient	Existing culvert	4.0%	2.6.2 Existing Conditions
	Reference reach	3.7%	2.7.1 Reference Reach Selection
	Proposed	3.8%	4.1.3 Channel Gradient
Hydraulic width	Existing	3 ft	2.6.2 Existing Conditions
	Proposed	18 ft	4.2.2 Hydraulic Width
	Added for climate resilience	No	4.2.2 Hydraulic Width
Vertical clearance	Required freeboard	1 ft	4.2.3 Vertical Clearance
	Required freeboard applied to 100 yr or 2080, 100 yr	2080, 100 yr	4.2.3 Vertical Clearance
	Maintenance clearance	Required10 ft	4.2.3 Vertical Clearance
	Low chord elevation	Downstream: 57.5 ft; Upstream: 61.2 ft	4.2.3 Vertical Clearance
Crossing length	Existing	119 ft	2.6.2 Existing Conditions
	Proposed	96 ft	4.2.4 Hydraulic Length
Structure type	Recommendation	No	4.2.6 Structure Type
	Type	N/A	4.2.6 Structure Type
Substrate	Existing	See Section 2.7.3	2.7.3 Sediment
	Proposed	See Section 4.3.1	4.3.1 Bed Material
	Coarser than existing?	No	4.3.1 Bed Material

Stream crossing category	Element	Value	Report location
Channel complexity	LWM for bank stability	No	4.3.2 Channel Complexity
	LWM for habitat	Yes	4.3.2 Channel Complexity
	LWM within structure	No	4.3.2 Channel Complexity
	Meander bars	No	4.3.2 Channel Complexity
	Boulder clusters	Habitat boulders only	4.3.2 Channel Complexity
	Coarse bands	No	4.3.2 Channel Complexity
	Mobile wood	Yes, only SWM	4.3.2 Channel Complexity
Floodplain continuity	FEMA mapped floodplain	No	6 Floodplain Evaluation
	Lateral migration	Yes	2.7.5 Channel Migration
	Floodplain changes?	Yes	6 Floodplain Evaluation
Scour	Analysis	See Section 7	7 Preliminary Scour Analysis
	Scour countermeasures	Determined at FHD	8 Scour Countermeasures
Channel degradation	Potential?	Yes	7.2 Long-term Degradation of the Channel Bed
Channel degradation	Allowed?	Yes	7.2 Long-term Degradation of the Channel Bed

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Appendices

Appendix A: FEMA Floodplain Map

Appendix B: Hydraulic Field Report Form

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix E: Manning's Calculations

Appendix F: Large Woody Material Calculations

Appendix G: Future Projections for Climate-Adapted Culvert Design

Appendix H: SRH-2D Model Results

Appendix I: SRH-2D Model Stability and Continuity

Appendix J: Reach Assessment

Appendix K: Scour Calculations (FHD ONLY)

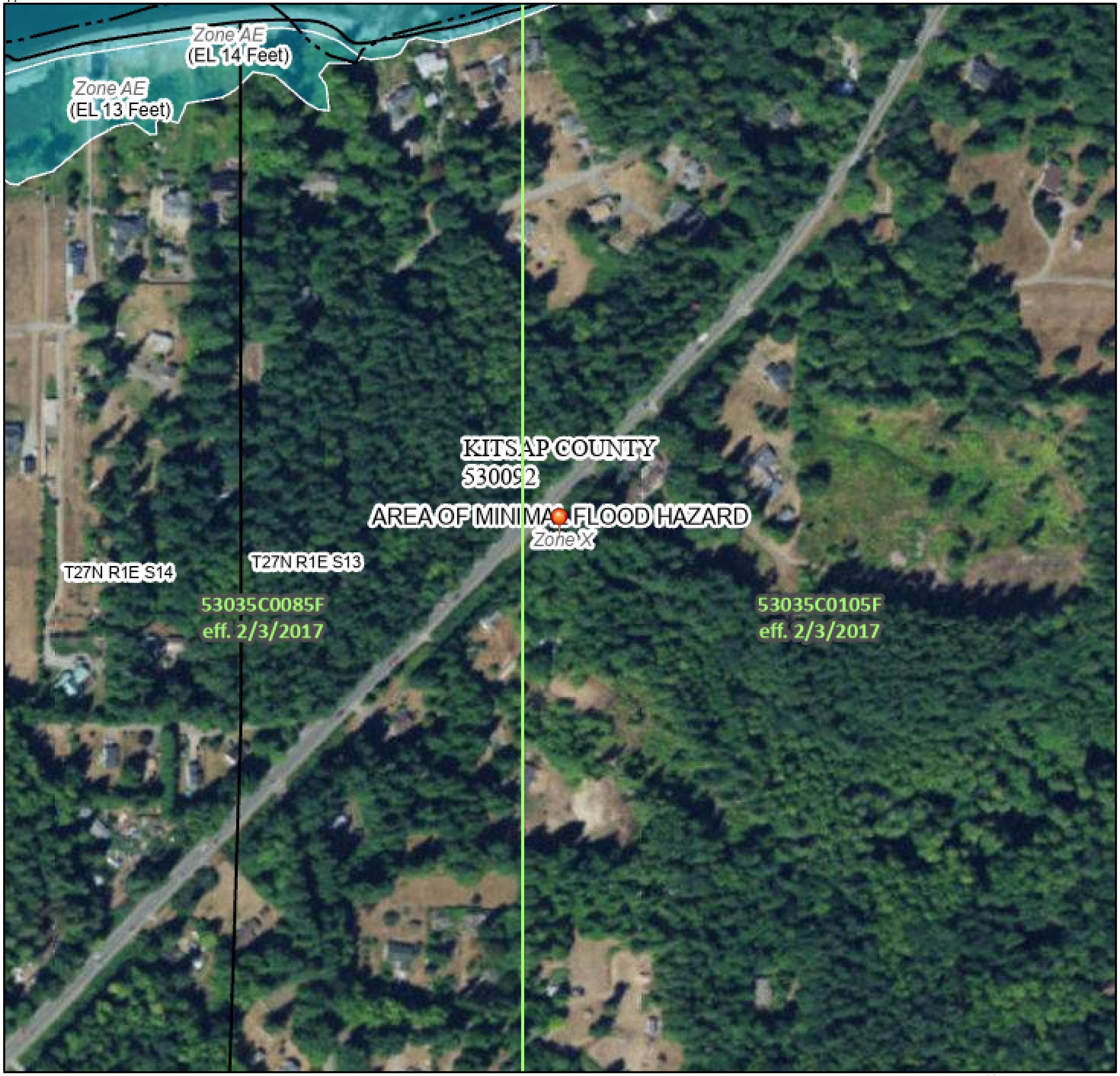
Appendix L: Floodplain Analysis (FHD ONLY)

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

Appendix N: Hydrology

Appendix A: FEMA Floodplain Map

FEMA


Zone AE
(EL 14 Feet)
Zone AE
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KITSAP COUNTY
530092
AREA OF MINIMAL FLOOD HAZARD
Zone X
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T27N R1E S13
53035C0085F
eff. 2/3/2017
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eff. 2/3/2017

Appendix B: Hydraulic Field Report Form

Hydraulics Section	Hydraulics Field Report	Project Number: Y-12554
	Project Name: PHD Spring Creek to Hood Canal	Date: Nov. 30, 2021
	Project Office: Jacobs Engineering Group Inc Bellevue, WA	Time of Arrival: 2 PM
	Stream Name: Spring Creek	Time of Departure: 4:30 PM
WDFW ID Number: 990395	Tributary to: Hood Canal	Weather: Cloudy, 50 degrees
State Route/MP: SR 3/58.49	Township/Range/Section/ ¼ Section: Township 26 North, Range 01 East, Section 21	Prepared By: Jacobs Engineering Group Inc.
County: Kitsap	Purpose of Site Visit: Site visit #2.	WRIA: 15

Meeting Location:

On site

Attendance List:

Name	**Organization**	**Role**
Nicholas VanBuecken	Jacobs	Stream Engineer
Sage Jensen	Jacobs	Fisheries Biologist
Channing Syms	Jacobs	Stream Engineer
Mark Indrebo	Jacobs	Geomorphologist
Karen Williams	Jacobs	Geomorphologist
Morgan Ruark	Jacobs	Hydraulic Engineer

Bankfull Width:

Describe measurements, locations, known history, summarize on site discussion.

Three bankfull width (BFW) measurements were made downstream of the SR3 crossing, and three BFW measurements were made upstream of the crossing. The downstream measurements ranged from 6 to 7 feet and the upstream measurements ranged from 5 to 9. Downstream measurements were made on run/glide channel types. These channel types are created upstream of periodic woody debris accumulations. Upstream measurements were made in riffles or glides. BFW was delineated by field indicators including cut banks, perennial vegetation and an adjacent, flatter depositional surface.

Reference Reach:

Describe location, known history, summarize on site discussion, appropriateness, bankfull measurement.

The reference reach was located approx. 100 feet downstream of the crossing, between two BFW measurement locations. The reference reach exhibits a run or glide morphology with an asymmetric cross-section. The thalweg is along one side of the cross-section, and the other side is a sandy, bar-like surface. Channel shape is wide and somewhat shallow. The reference reach is not dominated by the presence of woody material. This reach is typical for both the upstream and downstream reaches.

Data Collection:

Describe who was involved, extents collection occurred within.

The Spring Creek to Hood Canal crossing was visited by Jacobs staff on November 30th, 2021. Jacobs staff investigated approximately 200 ft upstream of the crossing to roughly200 ft downstream of the crossing. Staff measured several BFW measurements, pebble counts, and large woody material (LWM) in the system as noted throughout this field report. Additional observations on suitable habitat for anadromous and resident salmonids and trout were also made.

Observations:

Describe site conditions, channel geomorphology, habitat type and location, flow splits, LWM location and quantity, etc.

The channel is sited in a moderately confined valley but has a modest active floodplain that allows energy dissipation at overbank flow. The channel exhibits moderate amounts of coniferous woody debris that form periodic steps in the channel (Photo 1). These infrequent accumulations drive the formation of upstream, lower gradient run and glide channel types. These channel types are characterized by asymmetrically deposited sandy bars (Photos 2 and 3).

Downstream of each step is a deep pool providing rearing and refugia habitat for juvenile salmonids. Where woody debris accumulations are sparse, riffle channel type predominates (Photo 4). In these areas channel complexity and salmonid refugia is diminished. Five pieces of LWM were noted in the upstream reach, with estimated diameters ranging from 12 to 36 inches at the mid-point. Roots from both living trees and cedar stumps also interacted with stream flow, adding to channel complexity (Photo 5). The moderately confining valley prevents significant flow splits, and no floodplain channels were observed. Both the downstream and upstream reach present higher quality migration, spawning, rearing, and foraging habitat for all species of anadromous and resident salmonids noted to be present or with the potential to be present within this system. Riparian vegetation is greater than 150 ft on either side of the stream (Photo 6), consisting of mid to late seral stage coniferous forested assemblage, including mature Western red cedar and Western hemlock. In-channel complexity from legacy LWD and living tree root masses where present forms lateral and cross-channel pools and cut banks, more commonly present in the downstream reach. Substrate throughout the upstream and downstream reaches presents suitable spawning gravels, and areas of sand where the stream energy is lower. The upper watershed of this creek is within the Kitsap County Port Gamble Heritage Park

Pebble Counts:

Describe location of pebble counts if available.

Pebble counts were collected at two locations upstream and two locations downstream of the crossing (see attached field sketch). Overall, the results at all locations were similar, displaying a bi-modal distribution with peaks in the sand-sized particles and another in the 0.5 to 1.5 inch range. D50 ranged from 0.4 to 0.5 inches, and D84 from 1.3 to 1.7. Random, exhumed boulders were observed but do not appear to be part of the sediment load.

Photos:

Any relevant photographs placed here with descriptions.

Photo 1. Downstream section - Step formed by legacy LWM.


Photo 2. Downstream section - Looking downstream at run channel type with sand and gravel deposit at left side of channel and gravel bed and thalweg at right side of channel.


Photo 3. Downstream section - Looking upstream at run channel type with sandy deposit and opposing gravel bed and thalweg.

Photo 4. Upstream section - Where LWM is not present, riffle channel type dominates.

Photo 5. Upstream section - Roots add to channel complexity

Photo 6. Downstream section – Riparian vegetation community and presence of LWM

Samples:	
Work within the wetted perimeter may only occur during the time periods authorized in the APP ID 21036 entitled "Allowable Freshwater Work Times May 2018". Work outside of the wetted perimeter may occur year-round. APPS website: https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx	
Were any sample(s) collected from below the OHWM?	*No* ☒ *If no, then stop here.*
	Yes ☐ *If yes, then fill out the proceeding section for each sample.*

Sample #:	Work Start:	Work End:	Latitude:	Longitude:
Summary/description of location:				
Summarize/describe the sample location.				
Description of work below the OHWL:				
Describe the work below the OHWL, including equipment used and quantity of sediment sampled.				
Description of problems encountered:				
Describe any problems encountered, such as provision violations, notification, corrective action, and impacts to fish life and water quality from problems that arose.				

Concurrence Meeting	Date: 2/15/2022	Time of Arrival: 8:00 AM
Prepared By: Jacobs Engineering Group Inc.	Weather: 40s and overcast	Time of Departure: 10:00 AM

Attendance List:

Name	Organization	Role
Mark Indrebo	Jacobs Engineering	Geomorphologist
Reilly Holland	Jacobs Engineering	Stream Restoration Engineer
Ben Dupuy	Jacobs Engineering	Stream Restoration Engineer
Kate Fauver	WSDOT	Senior Planner
Heather Pittman	WSDOT	OR Design Manager
Damon Romero	WSDOT	Fish Biologist
Dave Molenaar	WSDOT	Biology Program Manager
Hunter Henderson	WSDOT	Associate Planner
Alison O’Sullivan	Suquamish Tribe	Fish Biologist
Marla Powers	Port Gamble S’Klallam Tribe	Environmental Planner
Shawn Stanley	WDFW	Habitat Engineer
Amber Martens	WDFW	Biologist
Gina Piazza	WDFW	Biologist

Bankfull Width:

An upstream bankfull width (BFW) measurement was taken with all attendees and was determined to be 7.5 feet.

Several downstream BFW measurement were taken with all attendees and was determined to be an average of 9 feet. Five BFW measurements were resulting in values of 6.5, 7.4, 7.5, 8.5 and 11 feet. Attendees agreed with a design BFW of 7.5 feet based on the field measurement taken at a straight section with no wood influence. Further discussion indicated a desire to accommodate wider areas up to 11-12 feet, which were comparable to some pools found in the system. Jacobs recommended designing the bed to a 7.5-foot width while adding a structure large enough to accommodate the 11-12 feet without hitting walls. Attendees concurred.

Reference Reach:

All attendees confirmed the selected downstream reference reach, approximately 100 feet from the outlet and spanning for approximately 100 feet, is appropriate. The channel is moderately confined with some floodplain. The reference reach primarily consists of longer (5-10 ft) riffles or runs separated by wood debris-facilitated steps that create deep pools. Jacobs suggested a channel profile including a step, pool, and tread, as described in Figure 2C of Church & Zimmerman (2007). This channel type is appropriate for the existing slope and agreed upon BFW and resembles the existing condition of the reference reach.

W03415 CHURCH AND ZIMMERMANN: RESEARCH PROGRESS ON STEP-POOL CHANNELS W03415

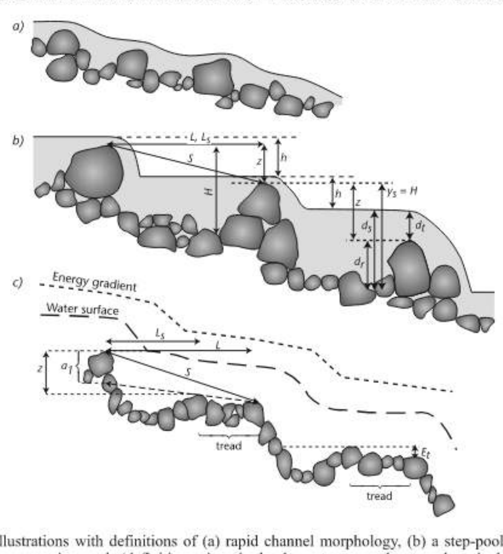


Figure 2. Illustrations with definitions of (a) rapid channel morphology, (b) a step-pool unit with no tread between successive pools (definitions given in the downstream pool are used particularly in studies of pool scour), and (c) a step-pool unit with a tread, extended forms of which may be considered equivalent to a run.

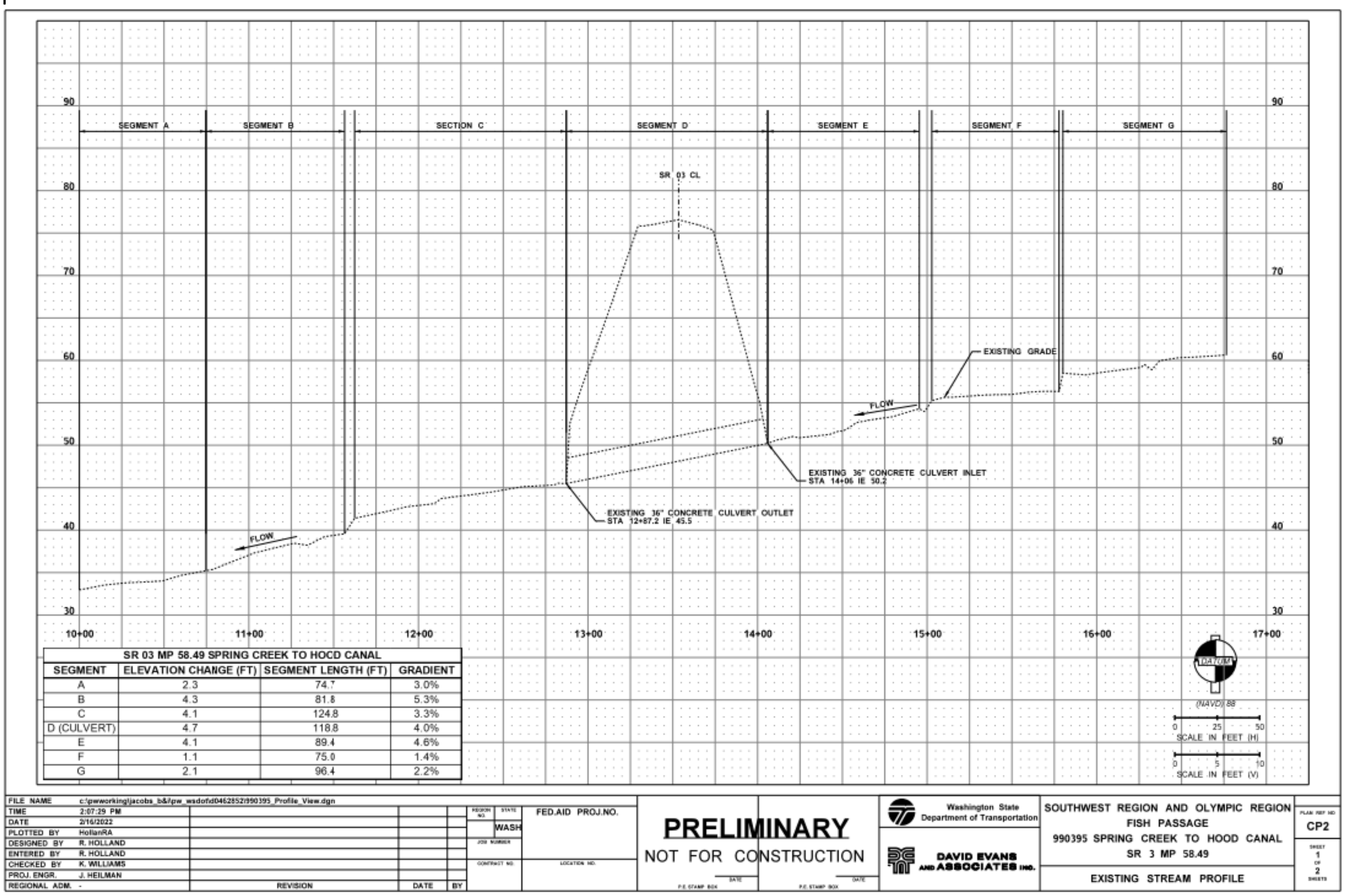
The current volume of large woody material (LWM) was well below the Fox and Bolton recommendation, thus additional LWM is suggested, and can be used to create the steps outside of the culvert. WSDOT expressed a strong desire to avoid placing wood within the proposed crossing, citing maintenance concerns.

Banks are well-vegetated and cohesive. The channel within the crossing structure will emulate these characteristics. Additional information on the reference reach can be found in the site visit two field report above.

Observations:

It was suggested that Jacobs should consider moving the upstream end of the proposed crossing approximately 25 feet to the north, to eliminate the sharp bend in the stream channel and reduce the skew of the culvert. It was also noted that such consideration be mindful of the balance of reg-alignment and associated grading with preserving existing high-quality trees.

Jacobs was asked to look at how the slope immediately upstream of the culvert would vary if measured from the toe of the upstream step, rather than the top. This resulted in a decrease in Segment E (below) from 5.2% to 4.6%. It should be noted that these steps are deformable and transitory, so the overall gradient of the system in probably the more important metric for choosing the gradient of the crossing. Presently the gradient upstream of the culvert (segments E, F, and G) is 4%, and the gradient downstream (Segments A, B, and C) is 4.3%, with a total site gradient of 4.1%. See the profile below for more detail.



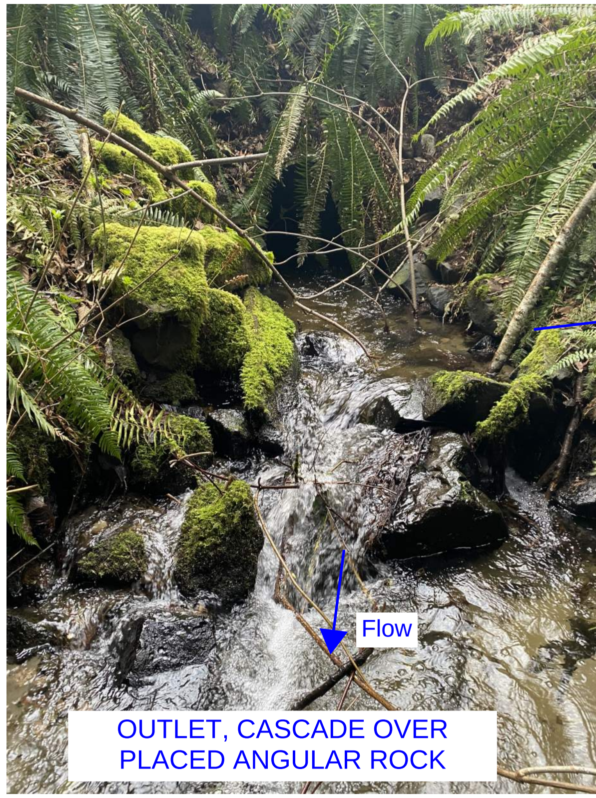
SR 03 MP 58.49 SPRING CREEK TO HOCD CANAL			
SEGMENT	ELEVATION CHANGE (FT)	SEGMENT LENGTH (FT)	GRADIENT
A	2.3	74.7	3.0%
B	4.3	81.8	5.3%
C	4.1	124.8	3.3%
D (CULVERT)	4.7	118.8	4.0%
E	4.1	89.4	4.6%
F	1.1	75.0	1.4%
G	2.1	96.4	2.2%

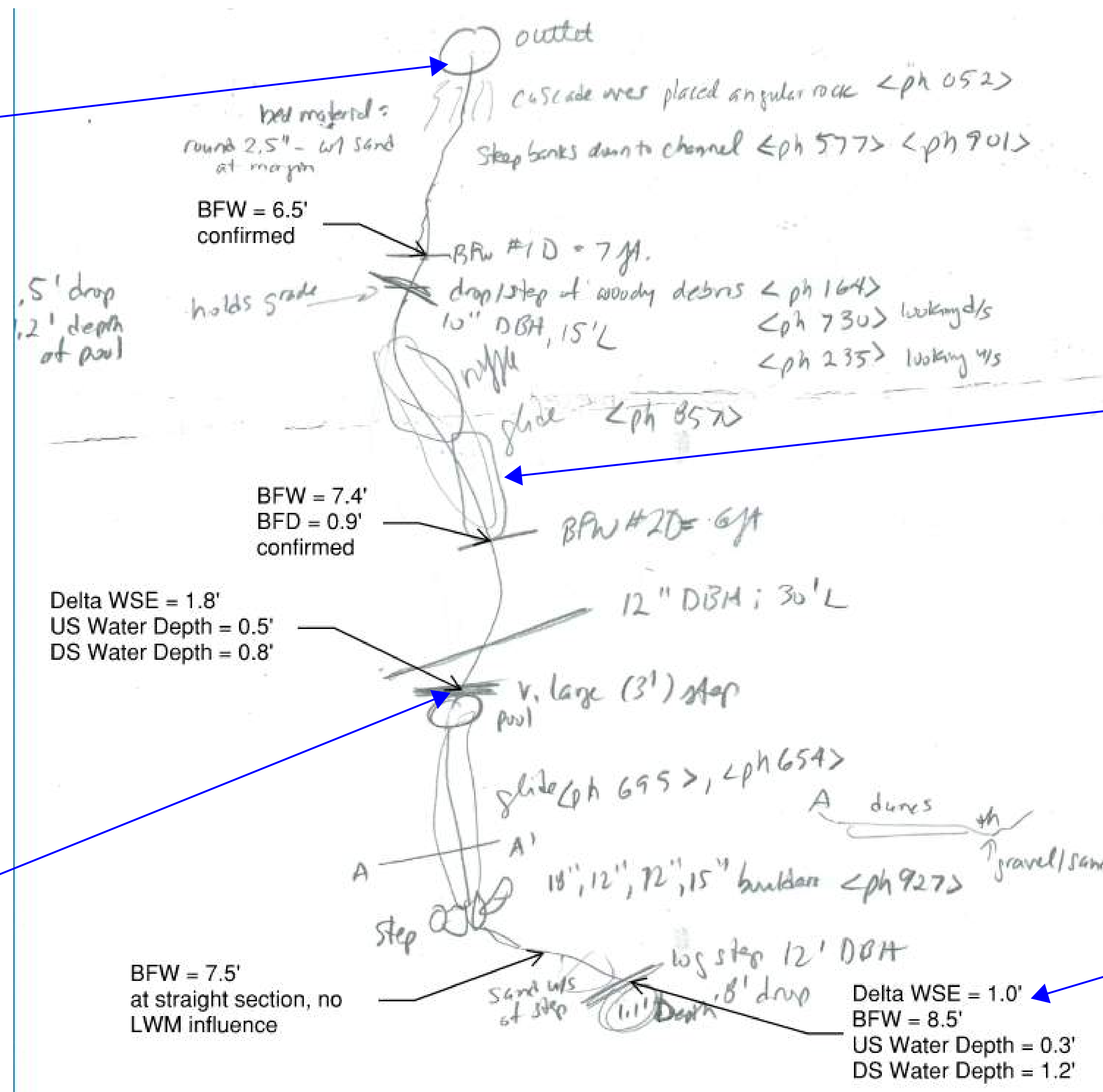
Please note there was an existing 32” CMP cut in half for road runoff both upstream and downstream that fed directly into the stream. Survey shows this runoff design only on the upstream side. The stump and structure location on the upstream side were confirmed.

Photos:

Site sketches with associated photos for the February 15th field visit is attached.

SITE SKETCH FROM SITE VISIT #2 ON 11/30/2021, DRAWN BY KAREN WILLIAMS
UPDATES FROM SITE VISIT #3 ON 2/15/2022, UPDATED BY REILLY HOLLAND





No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: R.HOLLAND
DRAWN BY: R.HOLLAND
CHECKED BY:
APPROVED BY:

Jacobs

REVIEWED BY:
SUBMITTED BY:
LINE IS 1" AT FULL SCALE

SCALE:
FILENAME:
CONTRACT No.: Y-12554
DATE: 11/29/2021

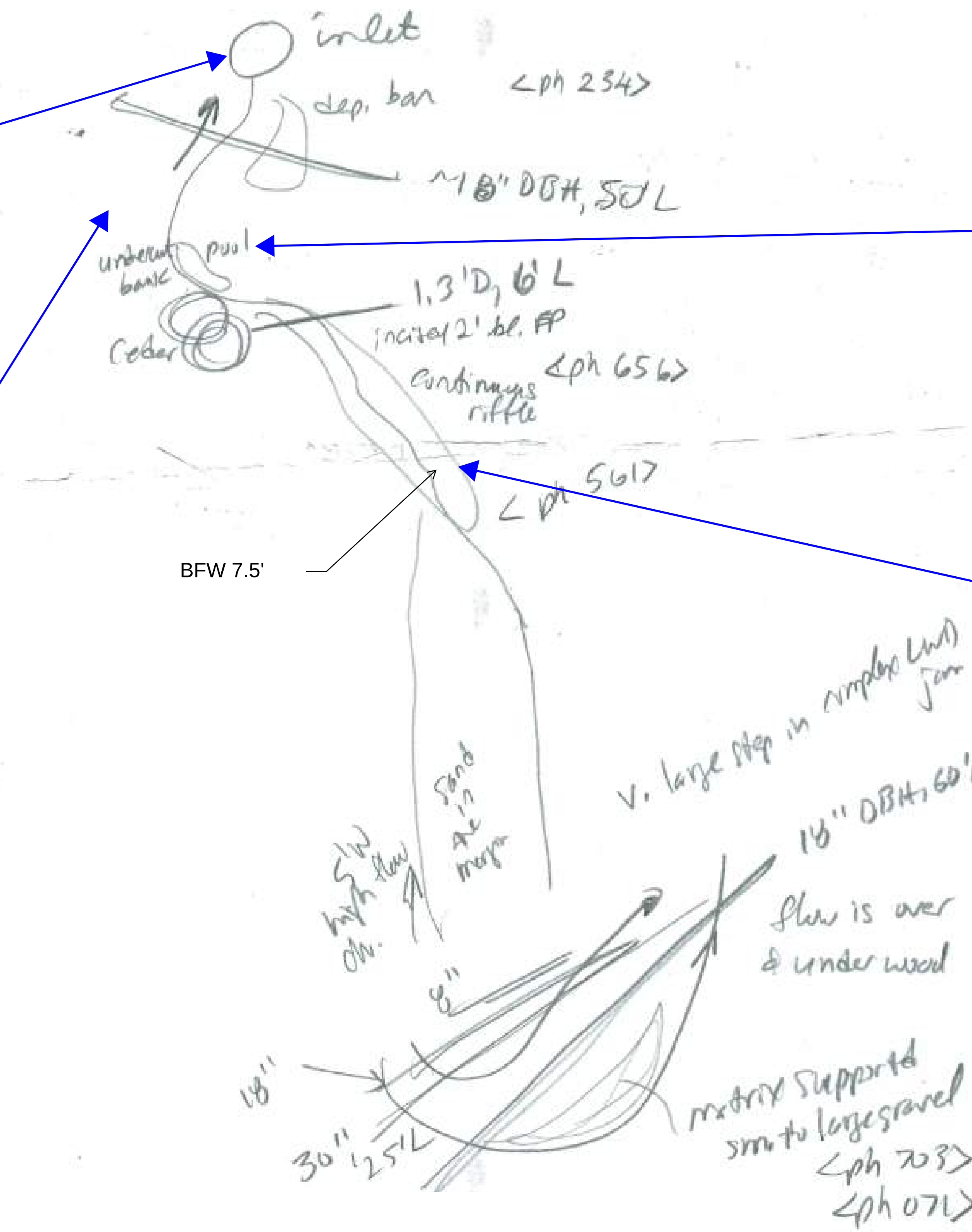
DESIGN PACKAGE:
PERMIT INFORMATION:

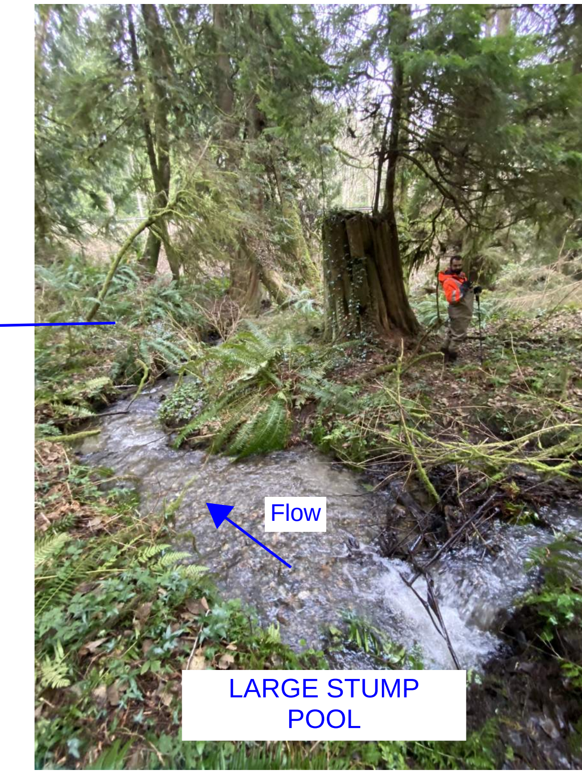
OLYMPIC REGION PHDS
Y-12554

990395 - SPRING CREEK TO HOOD CANAL
DOWNSTREAM SITE SKETCH

DRAWING No.: PLAN 1
FACILITY ID:
SHEET No.:
REV: 0

SITE SKETCH FROM SITE VISIT #2 ON 11/30/2021, DRAWN BY KAREN WILLIAMS
UPDATES FROM SITE VISIT #3 ON 2/15/2022, UPDATED BY REILLY HOLLAND





No.	DATE	DSN	CHK	APP	REVISION

DESIGNED BY: R.HOLLAND
DRAWN BY: R.HOLLAND
CHECKED BY:
APPROVED BY:

Jacobs

REVIEWED BY:
SUBMITTED BY:

LINE IS 1" AT FULL SCALE

SCALE:
FILENAME:
CONTRACT No.: Y-12554
DATE: 11/29/2021

DESIGN PACKAGE:
PERMIT INFORMATION:

OLYMPIC REGION PHDS
Y-12554

990395 - SPRING CREEK TO HOOD CANAL
UPSTREAM SITE SKETCH

DRAWING No.: **PLAN 1**
FACILITY ID:
SHEET No.:
REV: 0

Fish Passage Project Site Visit - Determining Project Complexity

PROJECT NAME:	Spring Creek
WDFW SITE ID:	990395
STATE ROUTE/MILEPOST:	SR 3 MP 58.49
SITE VISIT DATE:	12/1/2021
ATTENDEES:	Nich VanBuecken, Karen Williams, Sage Jensen, Channing Syms, Mark Indrebo
ANTICIPATED LEVEL OF PROJECT COMPLEXITY - Low/Medium/High (*additional considerations or red flags may trigger the need for new discussions*):	Medium due to gradient and confinement.
IN WATER WORK WINDOW	??

The following elements of projects should be discussed before the production of a Preliminary Hydraulic Design by members of WSDOT and WDFW to identify the level of complexity for each site, and corresponding communication and review. While certain elements may be categorized as indicators of a low/medium/high complexity project, these are only suggestions, and newly acquired information may change the level of complexity during a project. The ultimate documentation category for a given site is up to both WSDOT and WDFW, considering both site characteristics and synergistic effects.

Discuss the following elements as they apply to the project. Rank each element as low, medium, or high in complexity. If there are items that need follow-up, mark those and provide a brief description in the column labeled, “Is follow up needed on this item?” The assigned level of complexity determines the appropriate agreed upon review from WDFW. Ultimately, WSDOT needs to acquire an HPA from WDFW for fish passage projects and the agreed upon communication and review of project elements will contribute to efficiencies in the permitting process.

Fish Passage Project Site Visit - Determining Project Complexity

Project Elements (anticipated)	Low Complexity	Medium Complexity	High Complexity	Is follow up needed on this item?
Stream grading	X			limited channel regrade outside of crossing
Risk of degradation/aggradation	x			limited signs of high sediment load or active downcutting
Channel realignment	x			valley location set
Expected stream movement	x			mature trees and limited sediment load
Gradient		x		~2% culvert
Potential for backwater impacts	x			
Meeting requirements for freeboard	x			high roadway prism
Stream size, and Bankfull Width	x			BFW 5-9 ft
Slope ratio	x			TBD
Sediment supply	x			no evident excess supply
Meeting stream simulation	x			
Channel confinement		x		from unconfined upstream to confined downstream
Geotech or seismic considerations	x			no evidence
Tidal influence	x			no
Alluvial fan	x			no
Fill depth above barrier			x	~20 ft upstream and downstream
Presence of other nearby barriers	x			unknown
Presence of nearby infrastructure	x			
Need for bank protection	x			no acute ongoing erosion
Floodplain utilization ratio		x		appears unconfined upstream, confined downstream
Other:				

Appendix C: Streambed Material Sizing Calculations

Summary - Stream Simulation Bed Material Design - Main Channel

Project:	990395 Spring Ck to	SR	3	MP	58.49
By:	BD, PE	Checked By:		KW, PE	

Existing Gradation:

Location: US PC 1

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.09	0.03	0.01
in	3.60	1.10	0.40	0.08
mm	91.44	27.94	10.16	2.03

Existing Gradation:

Location: DS PC 3

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.08	0.03	0.00
in	3.60	0.90	0.40	0.05
mm	91.44	22.86	10.16	1.27

Existing Gradation:

Location: DS PC 4

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.09	0.04	0.00
in	5.00	1.10	0.50	0.02
mm	127.00	27.94	12.70	0.51

Design Gradation:

Location: Design Gradation

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.33	0.18	0.05	0.00
in	4.00	2.21	0.55	0.02
mm	101.60	56.25	13.84	0.41

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in — Equation E.6 $\tau_{ci} = 102.6\,\tau_{D50}\,D_i^{0.3}\,D_{50}^{0.7}$

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.044	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

Determining Aggregate Proportions

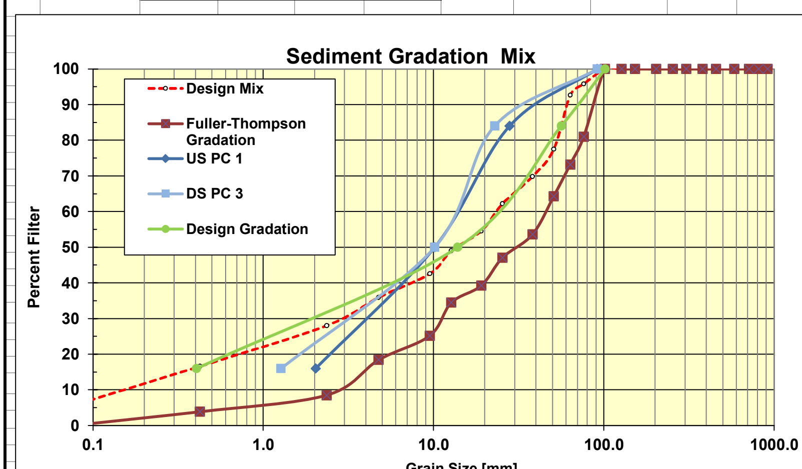
Per WSDOT Standard Specifications 9-03.11

Flow: 2-YR (7 cfs) / 100-YR (42 cfs)

Average Modeled Shear Stress (lb/ft^2): 0.88 / 2.23

	Rock Size [in]	[mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	2-YR (7 cfs)	100-YR (42 cfs)
Boulders	36.0	914										100	~~100.0~~	~~0.72~~	~~Motion~~	~~Motion~~
	32.0	813										50	~~100.0~~	~~0.70~~	~~Motion~~	~~Motion~~
	28.0	711									100		100.0	~~0.67~~	~~Motion~~	~~Motion~~
	23.0	584									50		100.0	~~0.63~~	~~Motion~~	~~Motion~~
	18.0	457								100			100.0	~~0.59~~	~~Motion~~	~~Motion~~
	15.0	381								50			100.0	~~0.55~~	~~Motion~~	~~Motion~~
Cobbles	12.0	305							100				100.0	~~0.52~~	~~Motion~~	~~Motion~~
	10.0	254						100	80				100.0	~~0.49~~	~~Motion~~	~~Motion~~
	8.0	203					100	80	68				100.0	~~0.46~~	~~Motion~~	~~Motion~~
	6.0	152				100	80	68	57				100.0	~~0.42~~	~~Motion~~	~~Motion~~
	5.0	127				80	68	57	45				100.0	~~0.40~~	~~Motion~~	~~Motion~~
	4.0	102			100	71	57	45	39				100.0	0.37	Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				95.8	0.34	Motion	Motion
	2.5	63.5		100	65	54	37	32	28				92.7	0.32	Motion	Motion
	2.0	50.8		80	50	45	29	25	22				77.5	0.30	Motion	Motion
	1.5	38.1		73	35	32	21	18	16				69.9	0.28	Motion	Motion
	1.0	25.4		65	20	18	13	12	11				62.2	0.25	Motion	Motion
	0.75	19.1		58	5	5	5	5	5				54.6	0.23	Motion	Motion
	0.50	12.7	100	50									49.0	0.20	Motion	Motion
	0.38	9.5	90	43									42.6	0.18	Motion	Motion
	No. 4 =	4.75	79	35									35.9			
	No. 8 =	2.36	67	26									28.0	Max Tau =		0.31
Sand	No. 40 =	0.425	37	16									16.6	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									5.5	D84 FOS	0.4	0.1
	% per category		19	60	21	0	0	0	0	0	0	0	--> 100%			
	% Cobble & Sediment		19.0	60.0	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0%			

%	mm	in	ft
5.5	0.1	0.0	
16	0.4	0.02	0.001
16.6	0.4	0.0	
49.00	12.7	0.5	
50	13.8	0.5	0.05
54.55	19.1	0.8	
77.50	50.8	2.0	
84	56.2	2.2	0.18
92.65	63.5	2.5	



Fuller-Thompson Gradation

Dmax = 101.6 | 4

D[mm]	D[in]	% passing
914.400	36	100.00
812.800	32	100.00
711.200	28	100.00
584.200	23	100.00
457.200	18	100.00
381.000	15	100.00
304.800	12	100.00
254.000	10	100.00
203.200	8	100.00
152.400	6	100.00
127.000	5	100.00
101.600	4	100.00
76.200	3	80.94
63.500	2.5	73.20
50.800	2	64.32
38.100	1.5	53.59
25.400	1.00	47.08
19.050	0.75	39.23
12.700	0.50	34.47
9.525	0.375	25.20
4.750	0.187	18.40
2.360	0.093	8.50
0.425	0.017	3.90
0.075	0.0030	0.00

Summary - Stream Simulation Bed Material Design - Floodplain

Project:	990395 Spring Ck to	SR	3	MP	58.49
By:	BD, PE	Checked By:		KW, PE	

Existing Gradation:

Location: US PC 1

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.09	0.03	0.01
in	3.60	1.10	0.40	0.08
mm	91.44	27.94	10.16	2.03

Existing Gradation:

Location: DS PC 3

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.08	0.03	0.00
in	3.60	0.90	0.40	0.05
mm	91.44	22.86	10.16	1.27

Existing Gradation:

Location: DS PC 4

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.09	0.04	0.00
in	5.00	1.10	0.50	0.02
mm	127.00	27.94	12.70	0.51

Design Gradation:

Location: Design Gradation

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.33	0.19	0.06	0.00
in	4.00	2.31	0.74	0.02
mm	101.60	58.68	18.75	0.53

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

Equation E.6 $\tau_{ci} = 102.6\ \tau_{D50}\ D_i^{0.3}\ D_{50}^{0.7}$

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.047	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

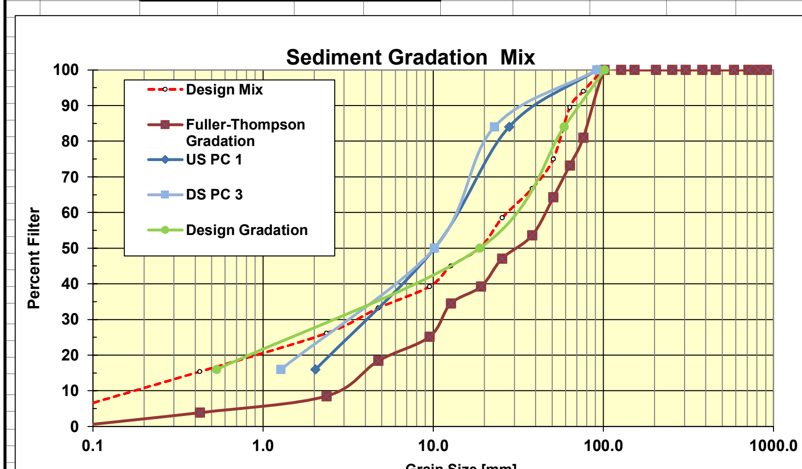
Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Flow	2-YR (7 cfs)	100-YR (42 cfs)
Average Modeled Shear Stress (lb/ft^2)		0.31	1.02

	Rock Size [in]	Rock Size [mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	2-YR	100-YR
Boulders	36.0	914										100	~~100.0~~	~~0.95~~	~~No Motion~~	~~Motion~~
	32.0	813										50	~~100.0~~	~~0.92~~	~~No Motion~~	~~Motion~~
	28.0	711									100		~~100.0~~	~~0.88~~	~~No Motion~~	~~Motion~~
	23.0	584									50		~~100.0~~	~~0.83~~	~~No Motion~~	~~Motion~~
	18.0	457								100			~~100.0~~	~~0.77~~	~~No Motion~~	~~Motion~~
	15.0	381								50			~~100.0~~	~~0.73~~	~~No Motion~~	~~Motion~~
Cobbles	12.0	305							100				~~100.0~~	~~0.68~~	~~No Motion~~	~~Motion~~
	10.0	254						100	80				~~100.0~~	~~0.65~~	~~No Motion~~	~~Motion~~
	8.0	203					100	80	68				~~100.0~~	~~0.61~~	~~No Motion~~	~~Motion~~
	6.0	152				100	80	68	57				~~100.0~~	~~0.56~~	~~No Motion~~	~~Motion~~
	5.0	127				80	68	57	45				~~100.0~~	~~0.53~~	~~No Motion~~	~~Motion~~
	4.0	102			100	71	57	45	39				100.0	0.49	No Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				94.0	0.45	No Motion	Motion
	2.5	63.5		100	65	54	37	32	28				89.5	0.43	No Motion	Motion
	2.0	50.8		80	50	45	29	25	22				75.0	0.40	No Motion	Motion
	1.5	38.1		73	35	32	21	18	16				66.8	0.37	No Motion	Motion
	1.0	25.4		65	20	18	13	12	11				58.5	0.32	No Motion	Motion
	0.75	19.1		58	5	5	5	5	5				50.3	0.30	Motion	Motion
	0.50	12.7	100	50									45.0	0.26	Motion	Motion
	0.38	9.5	90	43									39.3	0.24	Motion	Motion
	No. 4 =	4.75	79	35									33.2			
	No. 8 =	2.36	67	26									26.2	Max Tau =	0.42	
Sand	No. 40 =	0.425	37	16									15.4	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									4.9	D84 FOS	1.3	0.4
	% per category		20	50	30	0	0	0	0	0	0	0	*--> 100%*			
	% Cobble & Sediment		20.0	50.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*100.0%*			

%	mm	in	ft
15.4	0.4	0.0	
16	0.5	0.0	0.00
26.2	2.4	0.1	
45.00	12.7	0.5	
50	18.7	0.7	0.06
50.25	19.1	0.8	
75.00	50.8	2.0	
84	58.7	2.3	0.19
89.50	63.5	2.5	



Fuller-Thompson Gradation

Dmax = 101.6 4

D[mm]	D[in]	% passing
914.400	36	100.00
812.800	32	100.00
711.200	28	100.00
584.200	23	100.00
457.200	18	100.00
381.000	15	100.00
304.800	12	100.00
254.000	10	100.00
203.200	8	100.00
152.400	6	100.00
127.000	5	100.00
101.600	4	100.00
76.200	3	80.94
63.500	2.5	73.20
50.800	2	64.32
38.100	1.5	53.59
25.400	1.00	47.08
19.050	0.75	39.23
12.700	0.50	34.47
9.525	0.375	25.20
4.750	0.187	18.40
2.360	0.093	8.50
0.425	0.017	3.90
0.075	0.0030	0.00

Summary - Stream Simulation Bed Material Design - Step

Project:	990395 Spring Ck to	SR	3	MP	58.49
By:	BD, PE	Checked By:		KW, PE	

Existing Gradation:

Location: US PC 1

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.09	0.03	0.01
in	3.60	1.10	0.40	0.08
mm	91.44	27.94	10.16	2.03

Existing Gradation:

Location: DS PC 3

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.30	0.08	0.03	0.00
in	3.60	0.90	0.40	0.05
mm	91.44	22.86	10.16	1.27

Existing Gradation:

Location: DS PC 4

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.42	0.09	0.04	0.00
in	5.00	1.10	0.50	0.02
mm	127.00	27.94	12.70	0.51

Design Gradation:

Location: Design Gradation

	D_{100}	D_{84}	D_{50}	D_{16}
ft	1.50	0.66	0.16	0.01
in	18.00	7.94	1.92	0.16
mm	457.20	201.75	48.74	4.00

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

Equation E.6 $\tau_{ci} = 102.6\, \tau_{D50}\, D_i^{0.3}\, D_{50}^{0.7}$

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

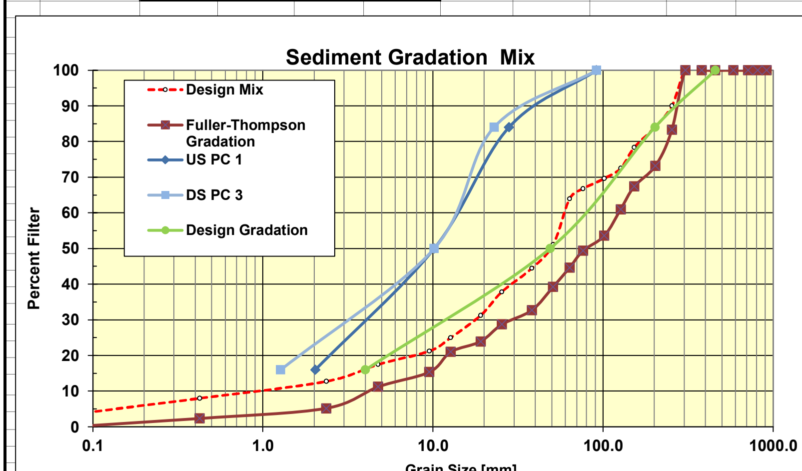
γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.052	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

	Rock Size [in]	Rock Size [mm]	Streambed Sand	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}	τ_{ci}	Flow 2-YR (7 cfs)	100-YR (42 cfs)
														Average Modeled Shear Stress (lb/ft^2)	0.88	2.23
Boulders	36.0	914										100	~~100.0~~	~~2.06~~	~~No Motion~~	~~Motion~~
	32.0	813										50	~~100.0~~	~~1.98~~	~~No Motion~~	~~Motion~~
	28.0	711									100		~~100.0~~	~~1.91~~	~~No Motion~~	~~Motion~~
	23.0	584									50		~~100.0~~	~~1.80~~	~~No Motion~~	~~Motion~~
	18.0	457								100			100.0	1.67	No Motion	Motion
	15.0	381								50			100.0	1.58	No Motion	Motion
Cobbles	12.0	305							100				100.0	1.48	No Motion	Motion
	10.0	254						100	80				90.0	1.40	No Motion	Motion
	8.0	203					100	80	68				84.2	1.31	No Motion	Motion
	6.0	152				100	80	68	57				78.3	1.20	No Motion	Motion
	5.0	127				80	68	57	45				72.5	1.14	No Motion	Motion
	4.0	102			100	71	57	45	39				69.6	1.06	No Motion	Motion
Gravel	3.0	76.2			80	63	45	38	34				66.8	0.98	No Motion	Motion
	2.5	63.5		100	65	54	37	32	28				63.9	0.92	No Motion	Motion
	2.0	50.8		80	50	45	29	25	22				51.1	0.86	Motion	Motion
	1.5	38.1		73	35	32	21	18	16				44.5	0.79	Motion	Motion
	1.0	25.4		65	20	18	13	12	11				37.9	0.70	Motion	Motion
	0.75	19.1		58	5	5	5	5	5				31.3	0.64	Motion	Motion
	0.50	12.7	100	50									25.0	0.57	Motion	Motion
	0.38	9.5	90	43									21.3	0.52	Motion	Motion
	No. 4 =	4.75	79	35									17.5			
	No. 8 =	2.36	67	26									12.8	Max Tau =		1.31
Sand	No. 40 =	0.425	37	16									8.0	Flow	Q2	Q100
Silt	No. 200 =	0.0750	7	7									3.5	D84 FOS	1.5	0.6
	% per category		0	50	0	0	0	0	50		0	0	--> 100%			
	% Cobble & Sediment		0.0	50.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	100.0%			

%	mm	in	ft
12.8	2.4	0.1	
16	4.0	0.2	0.01
17.5	4.8	0.2	
44.46	38.1	1.5	
50	48.7	1.9	0.16
51.07	50.8	2.0	
78.33	152.4	6.0	
84	201.7	7.9	0.66
84.17	203.2	8.0	



Fuller-Thompson Gradation

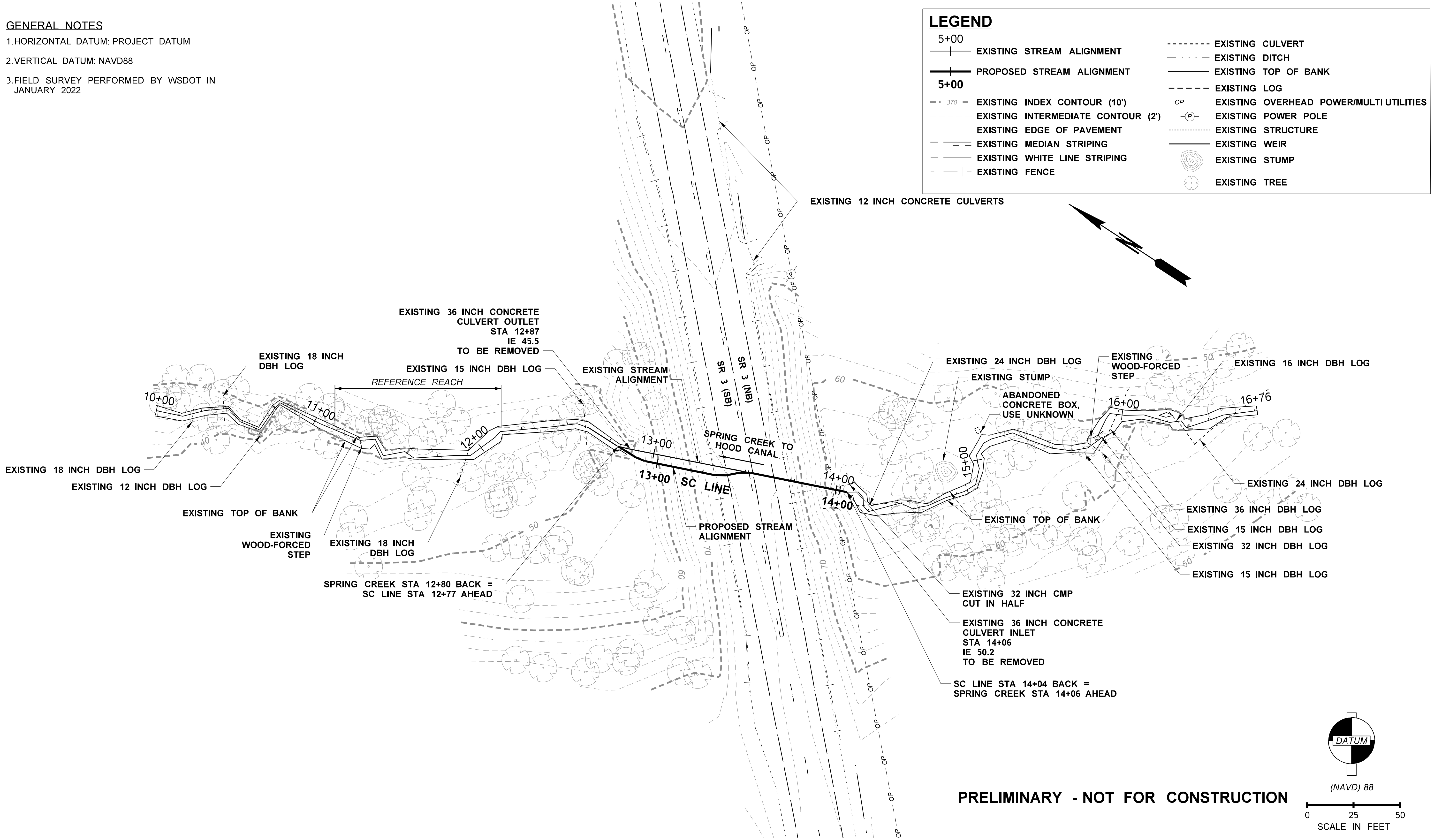
Dmax = 304.8 12

D[mm]	D[in]	% passing
914.400	36	100.00
812.800	32	100.00
711.200	28	100.00
584.200	23	100.00
457.200	18	100.00
381.000	15	100.00
304.800	12	100.00
254.000	10	83.32
203.200	8	73.20
152.400	6	67.44
127.000	5	61.00
101.600	4	53.59
76.200	3	49.37
63.500	2.5	44.65
50.800	2	39.23
38.100	1.5	32.69
25.400	1.00	28.72
19.050	0.75	23.93
12.700	0.50	21.02
9.525	0.375	15.37
4.750	0.187	11.22
2.360	0.093	5.19
0.425	0.017	2.38
0.075	0.0030	0.00

Appendix D: Stream Plan Sheets, Profile, Details

GENERAL NOTES

1. HORIZONTAL DATUM: PROJECT DATUM
2. VERTICAL DATUM: NAVD88
3. FIELD SURVEY PERFORMED BY WSDOT IN JANUARY 2022



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PROJ. ENGR.	J. HEILMAN			
REGIONAL ADM.	-	REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
Y12554		
CONTRACT NO.		LOCATION NO.

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

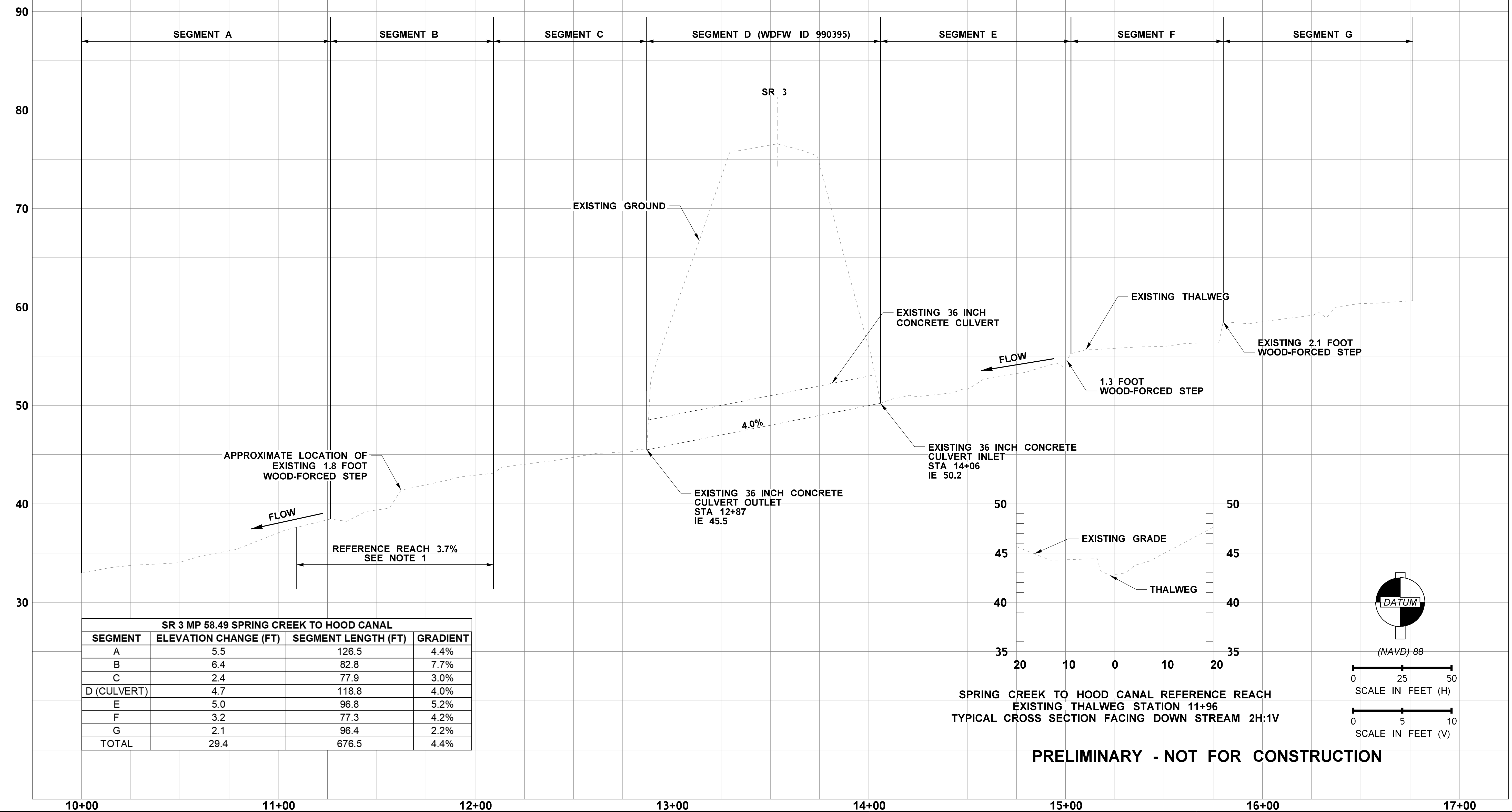
SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL
FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE1

SHEET 1 OF 6 SHEETS

NOTES
1. THE REFERENCE REACH GRADIENT OMITS THE MARKED ATYPICAL 1.8 FOOT DROP IN ORDER TO ACCURATELY REFLECT THE GEOMORPHIC FUNCTION OF THE OVERALL REACH.



SR 3 MP 58.49 SPRING CREEK TO HOOD CANAL			
SEGMENT	ELEVATION CHANGE (FT)	SEGMENT LENGTH (FT)	GRADIENT
A	5.5	126.5	4.4%
B	6.4	82.8	7.7%
C	2.4	77.9	3.0%
D (CULVERT)	4.7	118.8	4.0%
E	5.0	96.8	5.2%
F	3.2	77.3	4.2%
G	2.1	96.4	2.2%
TOTAL	29.4	676.5	4.4%

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JOB NUMBER Y12554
CONTRACT NO. | LOCATION NO.

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P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL
FISH BARRIER REMOVAL

EXISTING STREAM PROFILE

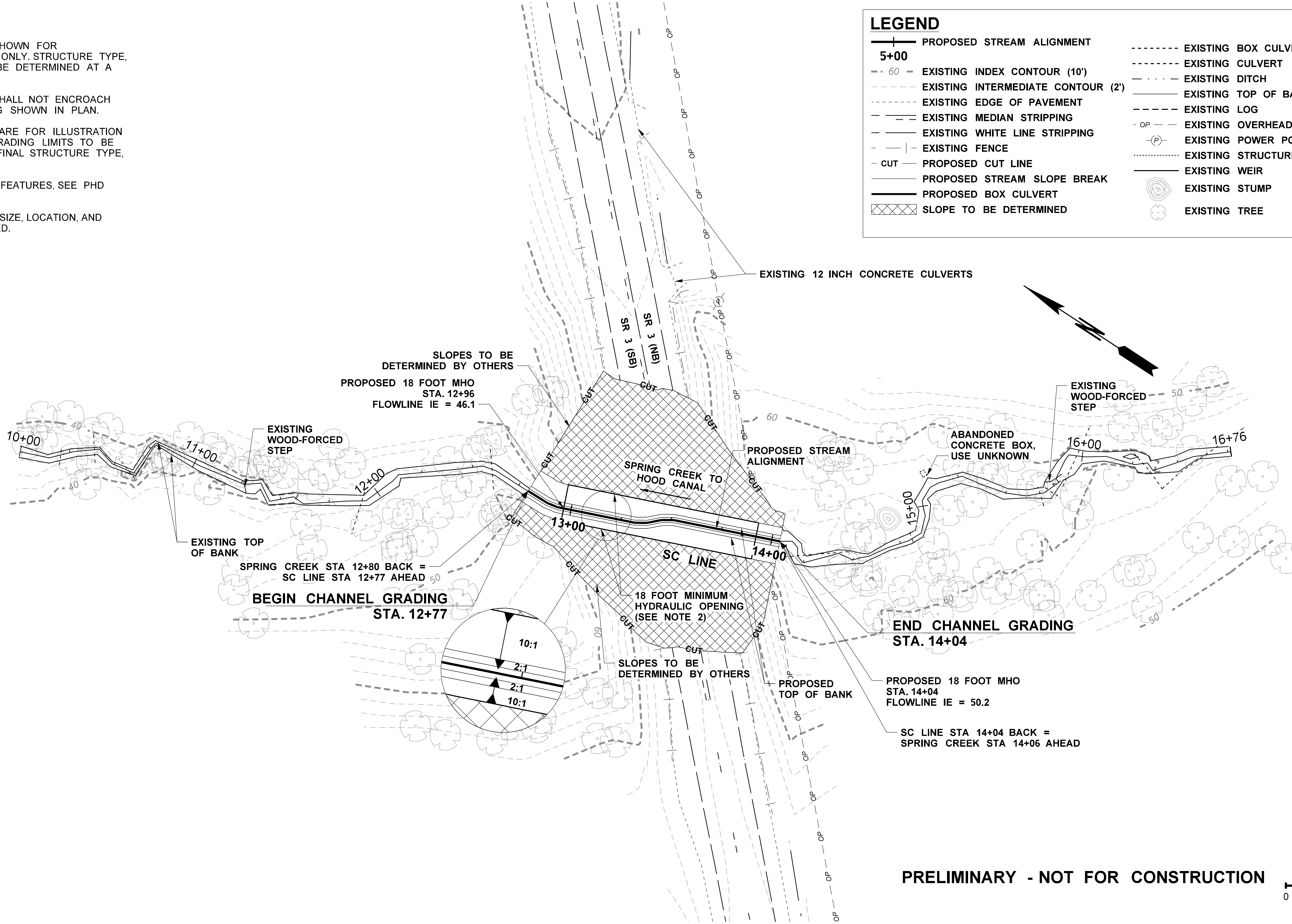
PLAN REF NO CP1
SHEET 2 OF 6 SHEETS

GENERAL NOTES

1. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATION PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED AT A LATER PHASE OF DESIGN.
2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN IN PLAN.
3. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE AND LOCATION.
4. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURE 30.
5. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

LEGEND

5+00 PROPOSED STREAM ALIGNMENT
60 EXISTING INDEX CONTOUR (10')
EXISTING INTERMEDIATE CONTOUR (2')
EXISTING EDGE OF PAVEMENT
EXISTING MEDIAN STRIPPING
EXISTING WHITE LINE STRIPPING
EXISTING FENCE
CUT PROPOSED CUT LINE
PROPOSED STREAM SLOPE BREAK
PROPOSED BOX CULVERT
SLOPE TO BE DETERMINED
EXISTING BOX CULVERT
EXISTING CULVERT
EXISTING DITCH
EXISTING TOP OF BANK
EXISTING LOG
OP EXISTING OVERHEAD POWER/MULTI UTILITIES
P EXISTING POWER POLE
EXISTING STRUCTURE
EXISTING WEIR
EXISTING STUMP
EXISTING TREE



PRELIMINARY - NOT FOR CONSTRUCTION

DATUM (NAVD) 88

0 25 50 SCALE IN FEET

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PROJ. ENGR.	J. HEILMAN		
REGIONAL ADM.	-	REVISION	DATE / BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.
JOB NUMBER Y12554
CONTRACT NO. | LOCATION NO.

P.E. STAMP BOX DATE | P.E. STAMP BOX DATE

Washington State Department of Transportation

SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL FISH BARRIER REMOVAL

PROPOSED STREAM PLAN

PLAN REF NO CR1

SHEET 3 OF 6 SHEETS

GENERAL NOTES

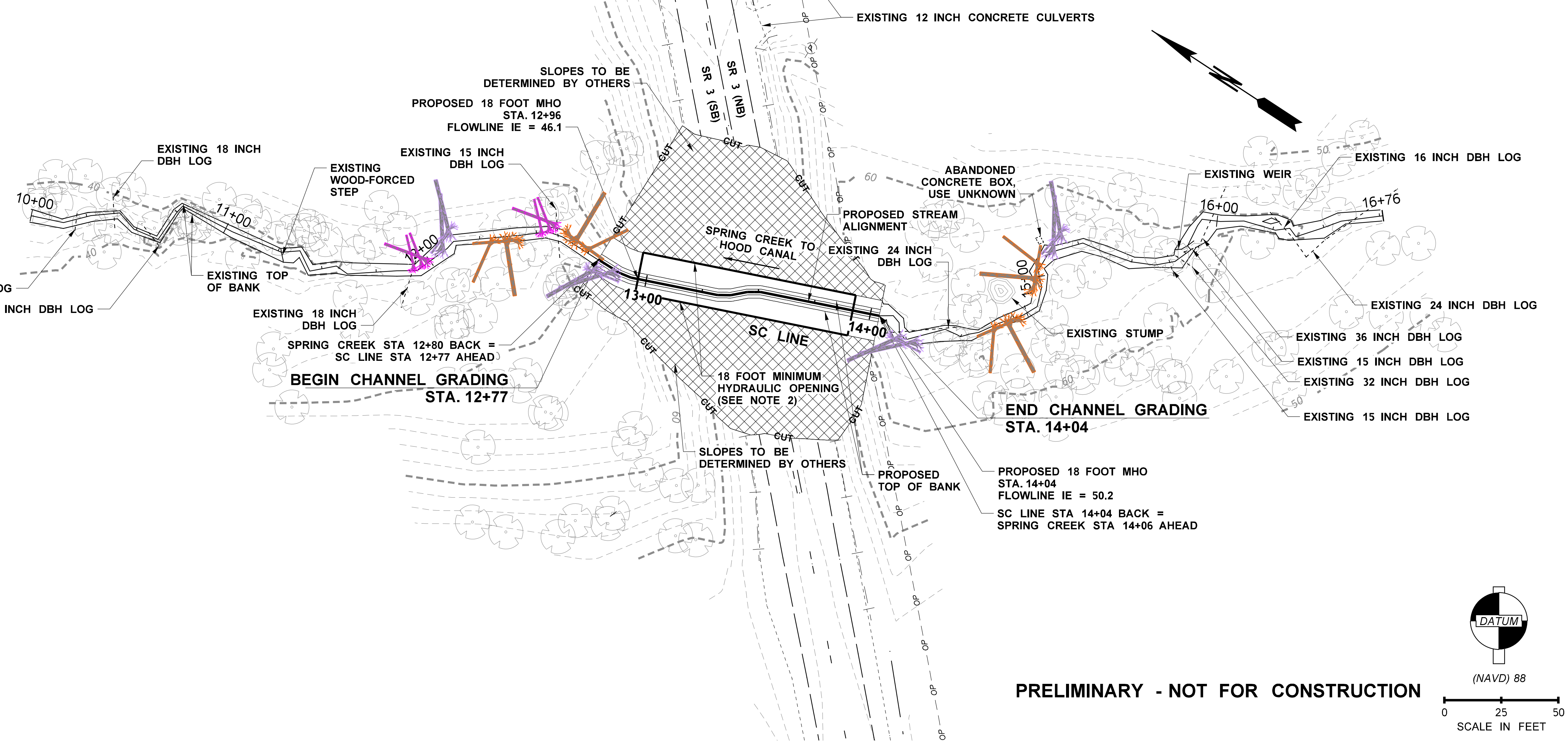
1. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATION PURPOSES ONLY. STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED AT A LATER PHASE OF DESIGN.
2. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN IN PLAN.
3. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE AND LOCATION.
4. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURE 30.
5. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

LARGE WOODY MATERIAL (LWM) LEGEND

- TYPE 1: TWO LARGE LWM WITH ROOT WADS AND ONE SMALL LWM WITH A ROOT WAD; STABLE AT Q100
- TYPE 2: TWO MEDIUM LWM WITH ROOT WADS AND ONE LARGE LWM WITH A ROOT WAD; STABLE AT Q100
- TYPE 3: TWO SMALL LWM WITH ROOT WADS AND ONE MEDIUM LWM WITH A ROOT WAD; MOBILE AT Q25

LEGEND

- 5+00 PROPOSED STREAM ALIGNMENT
- 60 EXISTING INDEX CONTOUR (10')
- EXISTING INTERMEDIATE CONTOUR (2')
- EXISTING EDGE OF PAVEMENT
- EXISTING MEDIAN STRIPPING
- EXISTING WHITE LINE STRIPPING
- EXISTING FENCE
- CUT PROPOSED CUT LINE
- PROPOSED STREAM SLOPE BREAK
- PROPOSED BOX CULVERT
- SLOPE TO BE DETERMINED
- EXISTING BOX CULVERT
- EXISTING CULVERT
- EXISTING DITCH
- EXISTING TOP OF BANK
- EXISTING LOG
- OP EXISTING OVERHEAD POWER/MULTI UTILITIES
- P EXISTING POWER POLE
- EXISTING STRUCTURE
- EXISTING WEIR
- EXISTING STUMP
- EXISTING TREE



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REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
Y12554		
CONTRACT NO.	LOCATION NO.	

P.E. STAMP BOX DATE

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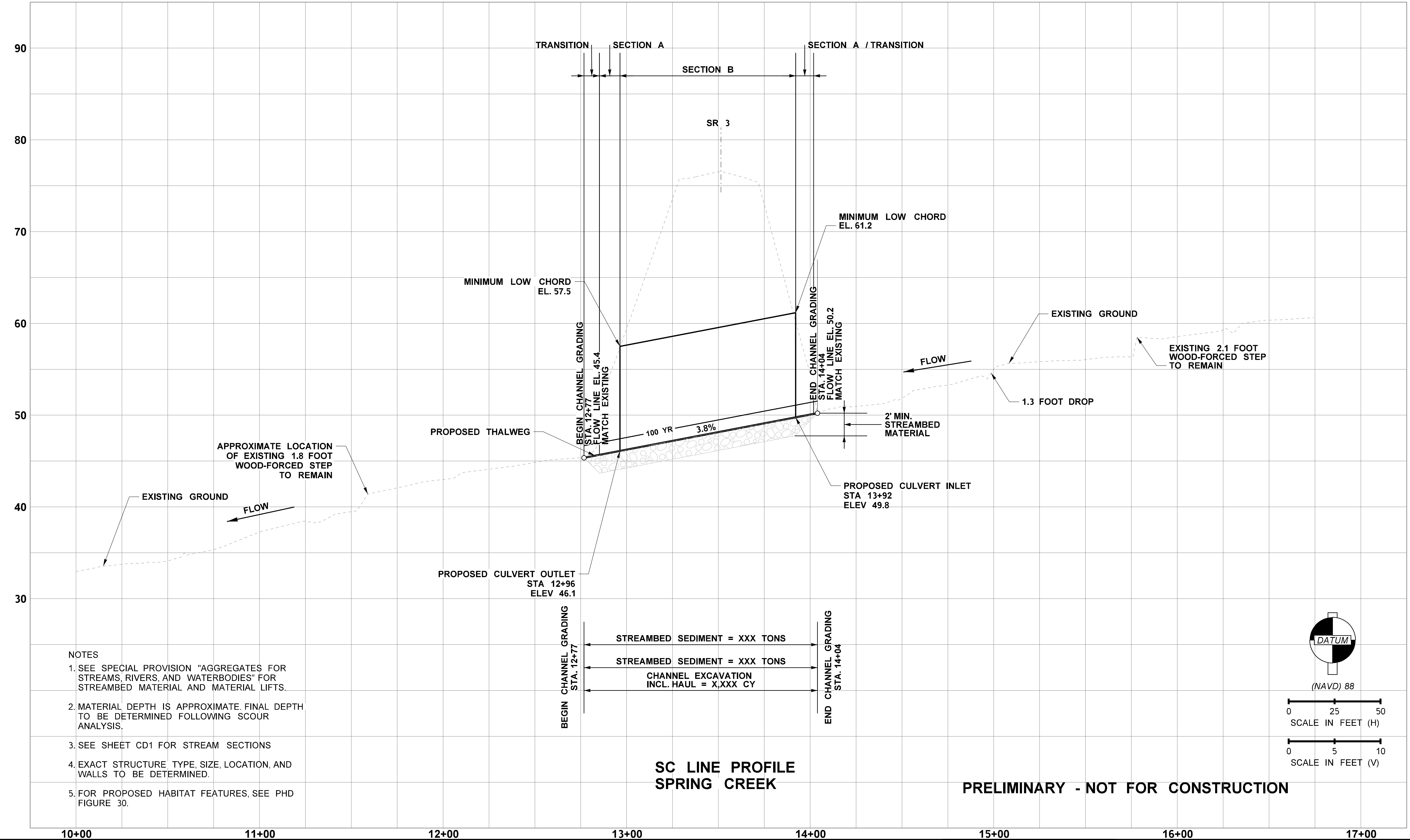
Washington State Department of Transportation

SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL FISH BARRIER REMOVAL

CONCEPT LWM PLAN

PLAN REF NO CR2

SHEET 4 OF 6 SHEETS



NOTES

1. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL AND MATERIAL LIFTS.
2. MATERIAL DEPTH IS APPROXIMATE. FINAL DEPTH TO BE DETERMINED FOLLOWING SCOUR ANALYSIS.
3. SEE SHEET CD1 FOR STREAM SECTIONS
4. EXACT STRUCTURE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.
5. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURE 30.

SC LINE PROFILE
SPRING CREEK

PRELIMINARY - NOT FOR CONSTRUCTION

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ENTERED BY	C. LARSEN
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REGIONAL ADM.	-

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
Y12554		
CONTRACT NO.		LOCATION NO.

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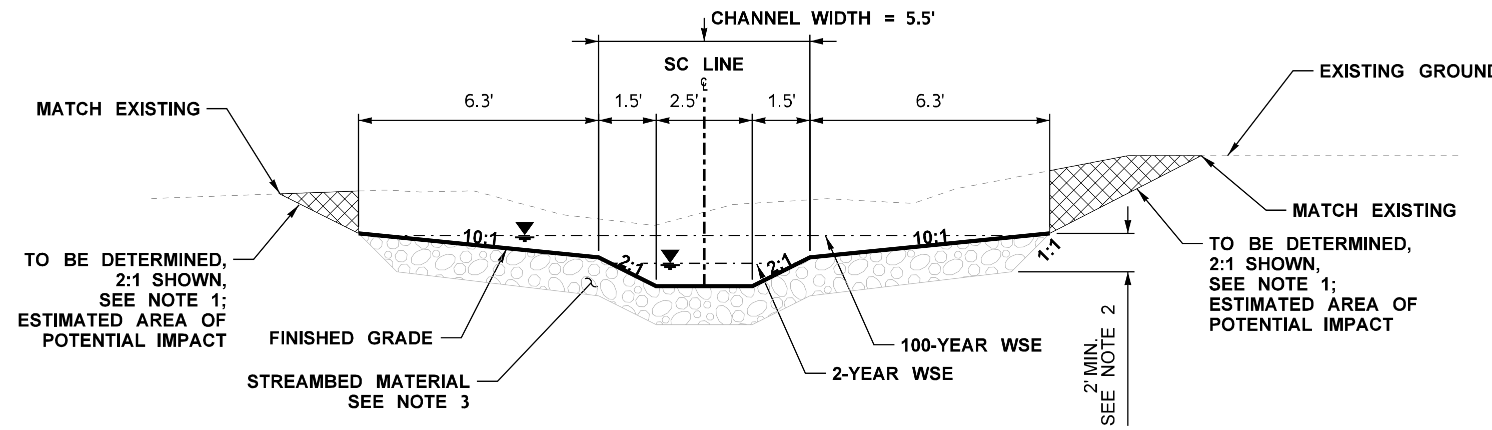
Washington State
Department of Transportation

SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL
FISH BARRIER REMOVAL

PROPOSED STREAM PROFILE

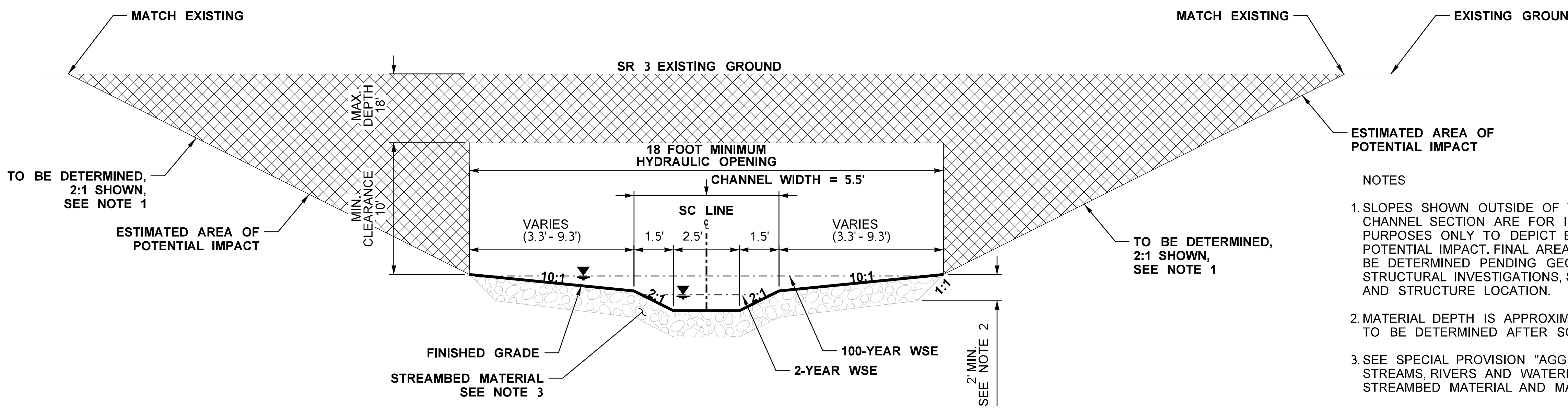
PLAN REF NO CP2

SHEET 5 OF 6 SHEETS



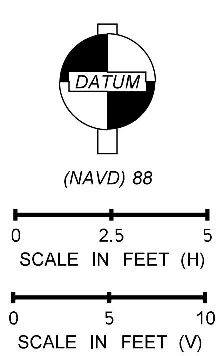
TYPICAL CHANNEL SECTION A

SC STA 12+77 TO SC STA 12+96
SC STA 13+92 TO SC STA 14+04



TYPICAL CHANNEL INSIDE STRUCTURE SECTION B

SC STA 12+96 TO SC STA 13+92



NOTES

1. SLOPES SHOWN OUTSIDE OF THE MINIMUM CHANNEL SECTION ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOTECHNICAL AND STRUCTURAL INVESTIGATIONS, STRUCTURE TYPE, AND STRUCTURE LOCATION.
2. MATERIAL DEPTH IS APPROXIMATE, FINAL DEPTH TO BE DETERMINED AFTER SCOUR ANALYSIS.
3. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS AND WATERBODIES" FOR STREAMBED MATERIAL AND MATERIAL LIFTS.
4. FROM STA. 12+77 TO 12+85, EVENLY TAPER TRANSITION TO MATCH EXISTING CHANNEL.
5. FROM STA. 13+92 TO 14+04, EVENLY TAPER TRANSITION TO MATCH EXISTING CHANNEL.
6. FOR PROPOSED HABITAT FEATURES, SEE PHD FIGURE 30.
7. FOR STREAMBED MATERIAL MIX TYPES AND LOCATIONS, SEE PHD NARRATIVE.

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JOB NUMBER Y12554
CONTRACT NO. | LOCATION NO.

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Washington State Department of Transportation

SR 3 MP 58.49
990395 SPRING CREEK TO HOOD CANAL FISH BARRIER REMOVAL

PROPOSED STREAM DETAILS

PLAN REF NO CD1
SHEET 6 OF 6 SHEETS

Appendix E: Manning's Calculations

There are no Manning's calculations for Spring Creek to Hood Canal at SR 3 MP 58.49.

Appendix F: Large Woody Material Calculations

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	*SR3, MP 58.49*		**Key piece volume**	*1.310*	*yd3*
Stream name	*Spring Creek*		**Key piece/ft**	*0.0335*	*per ft stream*
length of regrade[a]	*128*	*ft*	**Total wood vol./ft**	*0.3948*	*yd3/ft stream*
Bankfull width	*7.5*	*ft*	**Total LWM**[c] **pieces/ft stream**	*0.1159*	*per ft stream*
Habitat zone[b]	*Western WA*				

yes
no

Taper coeff.	-0.01554
LF_{rw}	1.5
H_{dbh}	4.5

Log type	*Diameter at midpoint (ft)*	*Length(ft)*[d]	*Volume (yd^3/log)*[d]	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*
A	2.14	*25*	3.33	**yes**	yes	12	39.96
B	1.19	*20*	0.82	**yes**	no	10	8.24
C	0.94	*15*	0.39	**yes**	no	8	3.08
D			0.00	**yes**			0.00
E			0.00	**yes**			0.00
F			0.00	**no**			0.00
G			0.00	**no**			0.00
H			0.00				0.00
I			0.00				0.00
J			0.00				0.00
K			0.00				0.00
L			0.00				0.00
M			0.00				0.00
N			0.00				0.00
O			0.00				0.00
P			0.00				0.00

DBH based on mid point diameter (ft)	$D_{root\ collar\ (ft)}$	L/2-Lrw (ft)
2.21	2.28	9.29
1.25	1.32	8.215
0.96	1.03	6.09
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0

Log volume for stability calcs (yd^3, per log)	
rootwad	bole
1.48	2.90
0.25	0.75
0.13	0.35
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00

	No. of key pieces	Total No. of LWM pieces	Total LWM volume (yd^3)
Design	12	30	51.3
Targets	**4**	**15**	**50.5**
	surplus	surplus	surplus

[a] includes length through crossing, regardless of structure type

[b] choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information

Western Washington lowla (generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine (generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa pine (mainly east slope Cascades below 3,700 ft. elevation)

[c]LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).

[d]includes rootwad if present

Key piece volume

BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Key Piece density lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Total Wood Volume lookup table

Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Number of LWM pieces lookup table

Habitat zone	BFW class (feet)	75th percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond.	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

Appendix G: Future Projections for Climate-Adapted Culvert Design

Future Projections for Climate-Adapted Culvert Design

Project Name: 990395

Stream Name: Spring Creek to Hood Canal

Drainage Area: 409 ac

Projected mean percent change in bankfull flow:

2040s: 12.4%

2080s: 14.5%

Projected mean percent change in bankfull width:

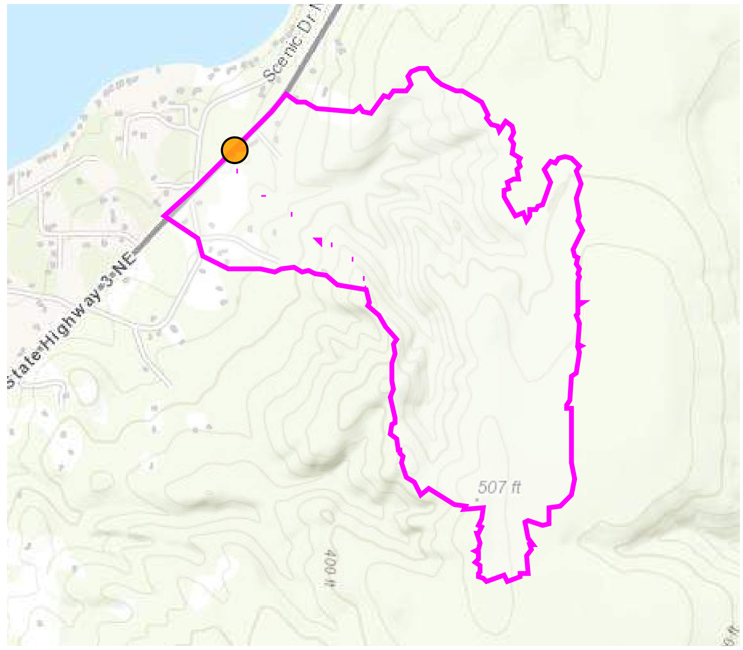
2040s: 6%

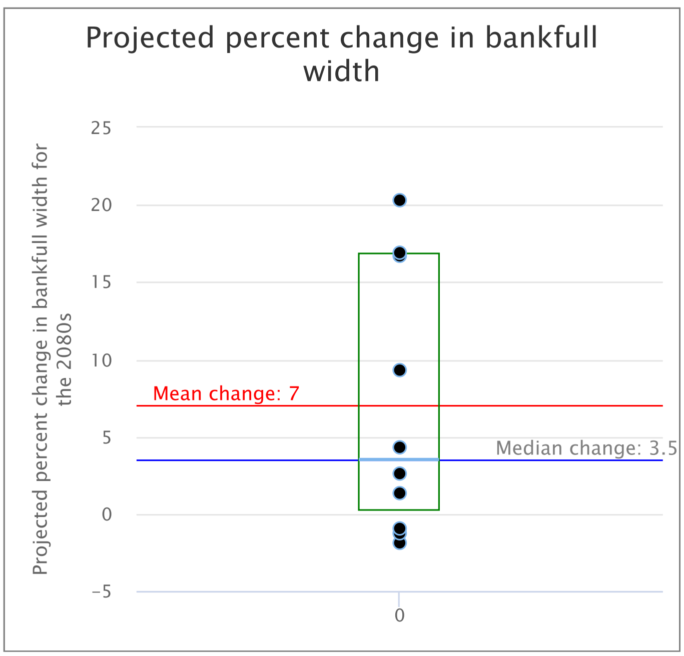
2080s: 7%

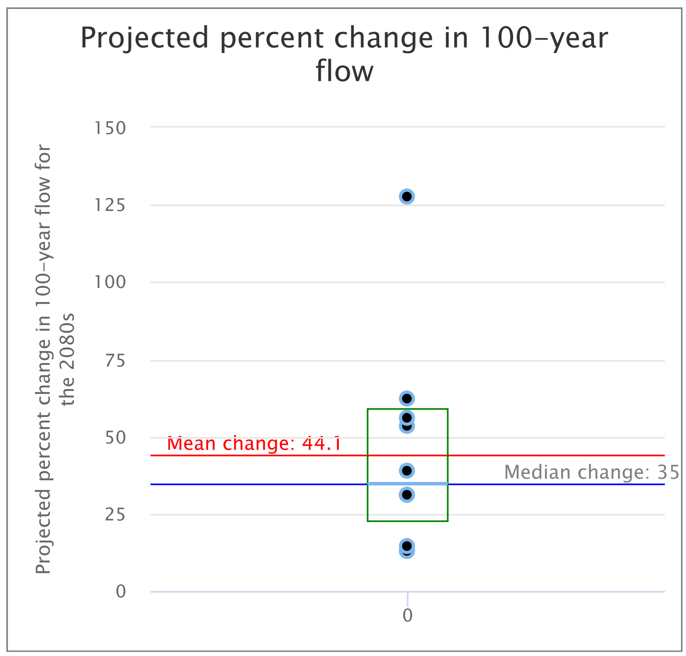
Projected mean percent change in 100-year flood:

2040s: 28.1%

2080s: 44.1%



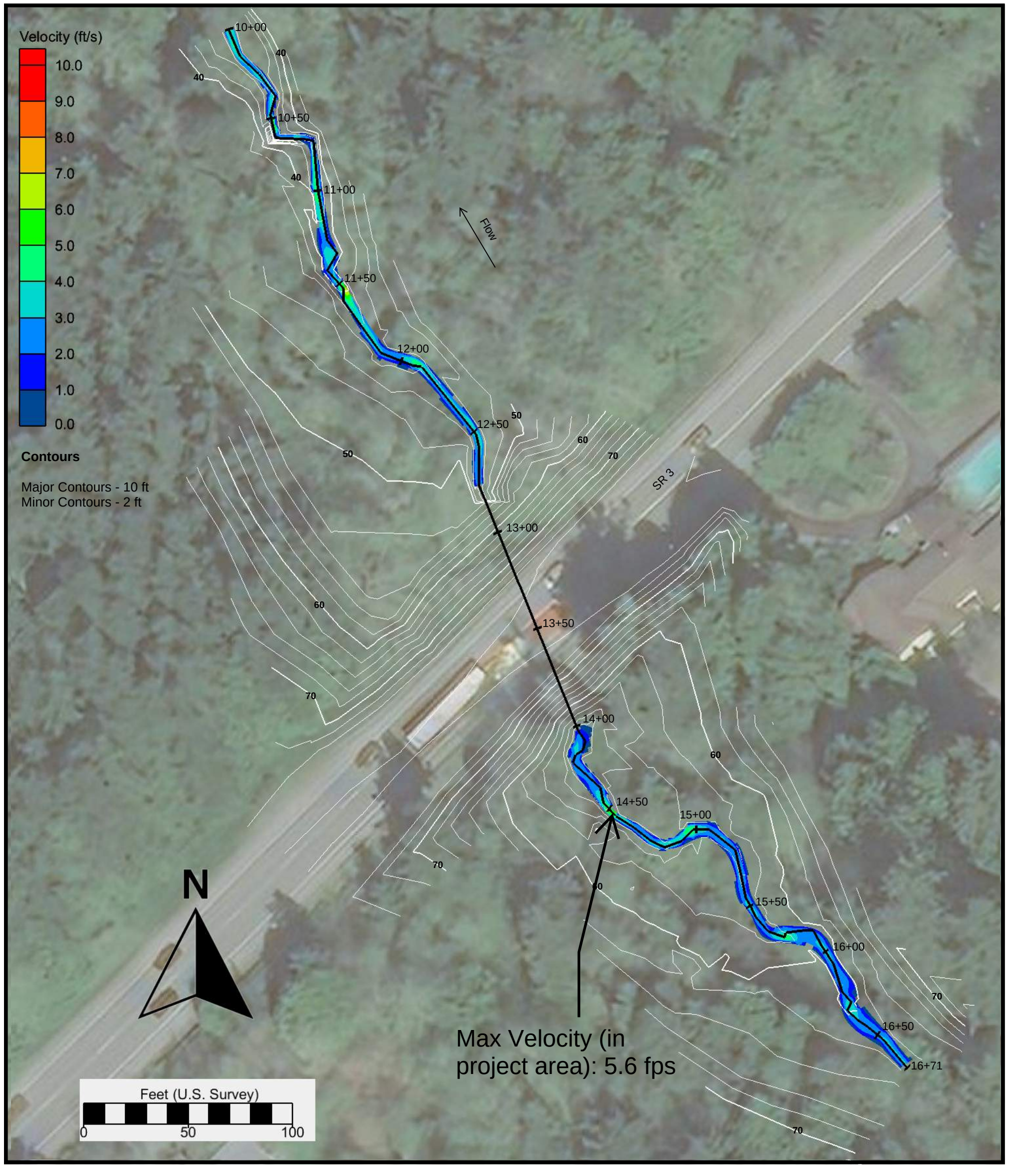




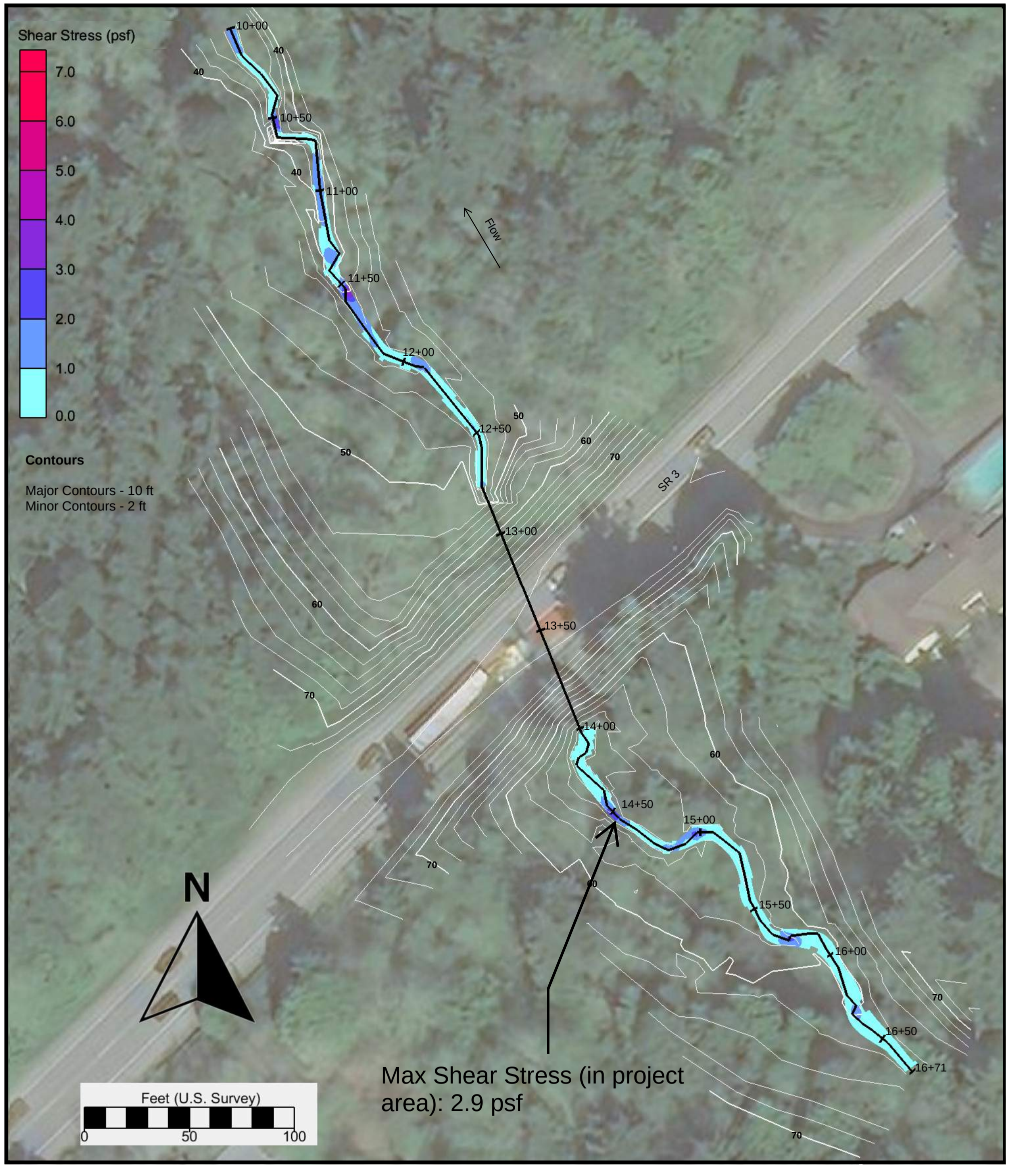
Black dots are projections from 10 separate models

Appendix H: SRH-2D Model Results

Existing Condition - Q2 Velocity (fps)

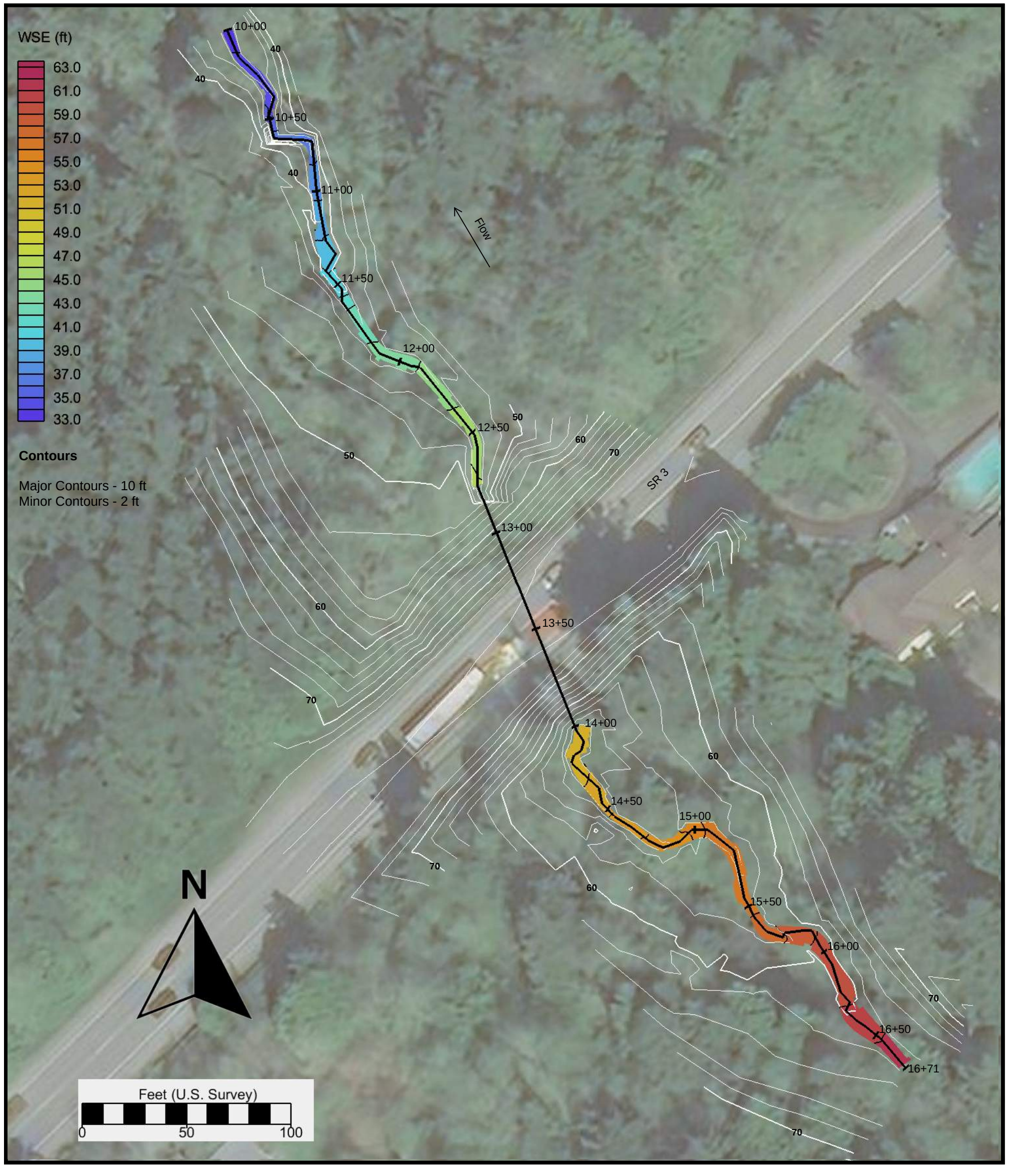


Existing Condition - Q2 Shear Stress* (psf)

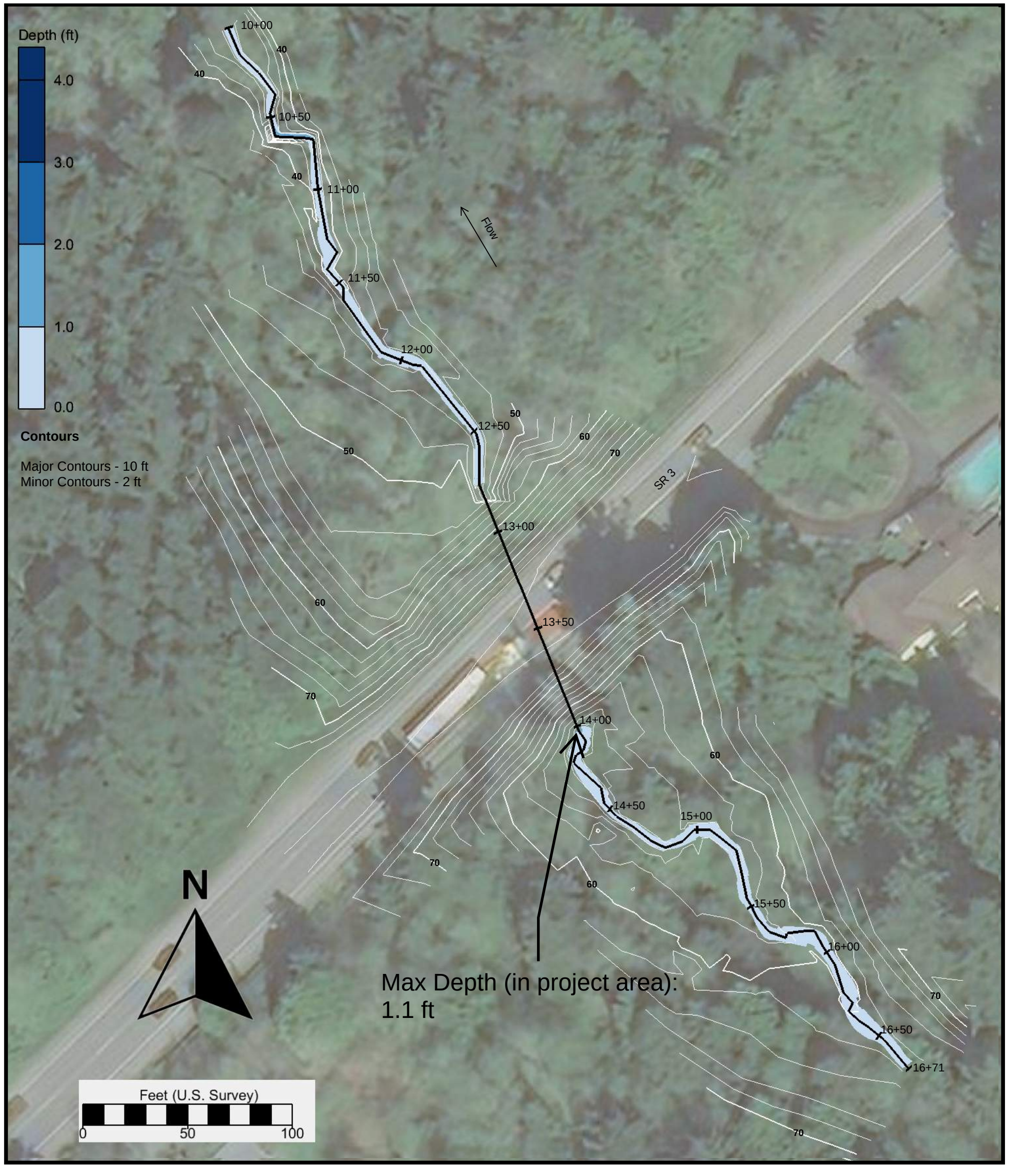


*Shear stress results are artificially elevated at the existing culvert outlet due to the high roughness region used to slow velocity closer to its field expected value and facilitate model stability.

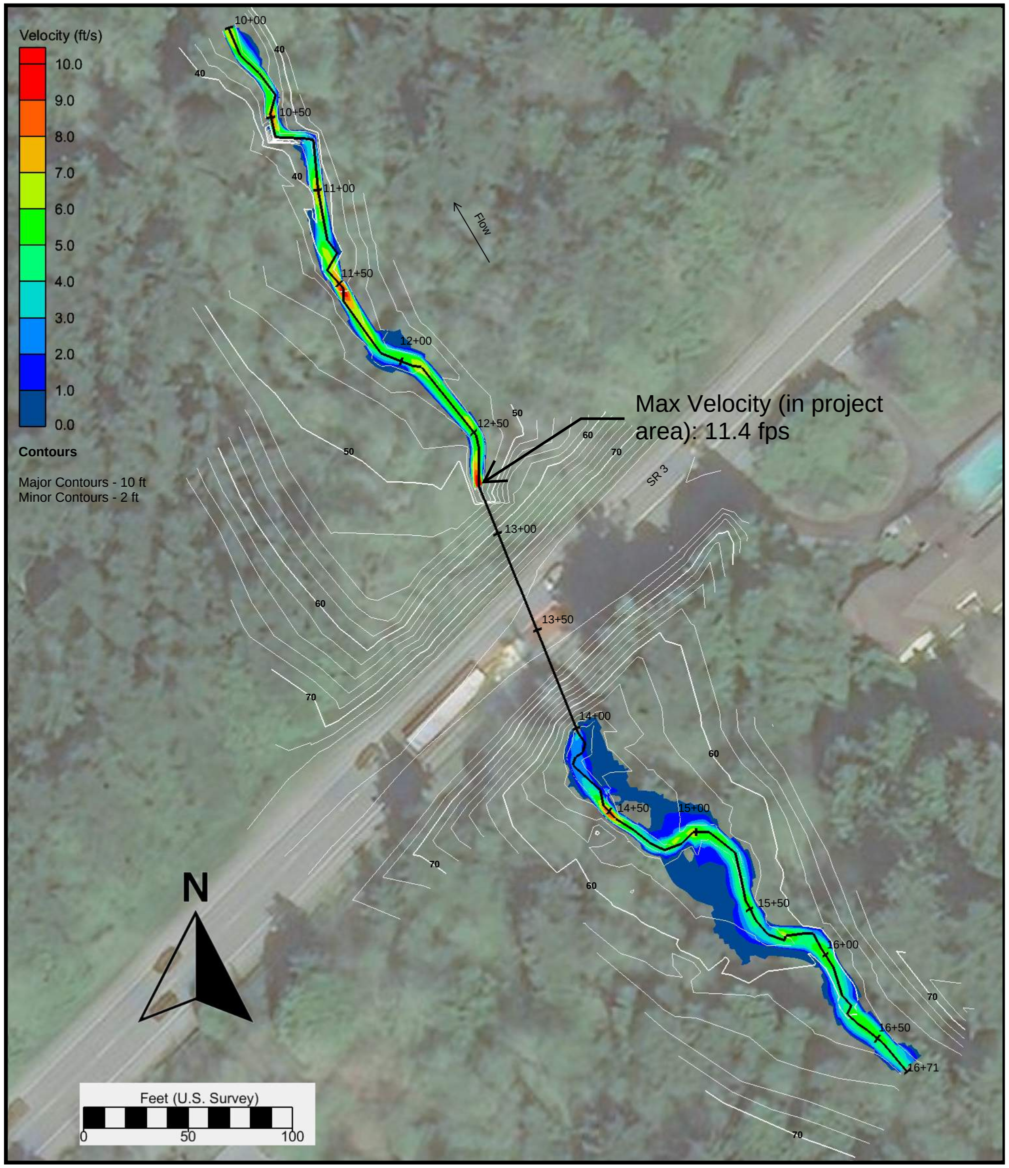
Existing Condition - Q2 WSE (NAVD88) (ft)



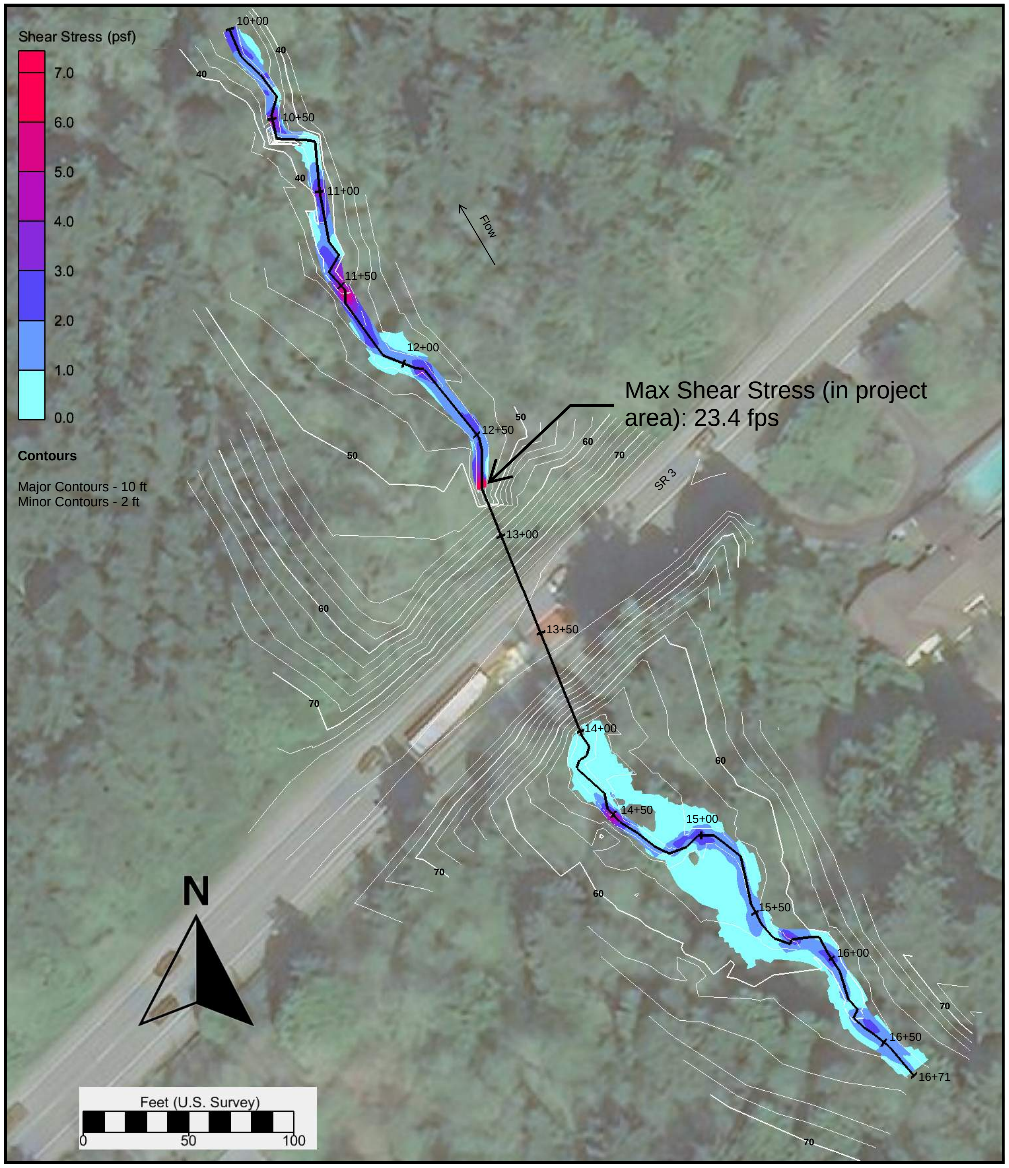
Existing Condition - Q2 Depth (ft)



Existing Condition - Q100 Velocity (fps)

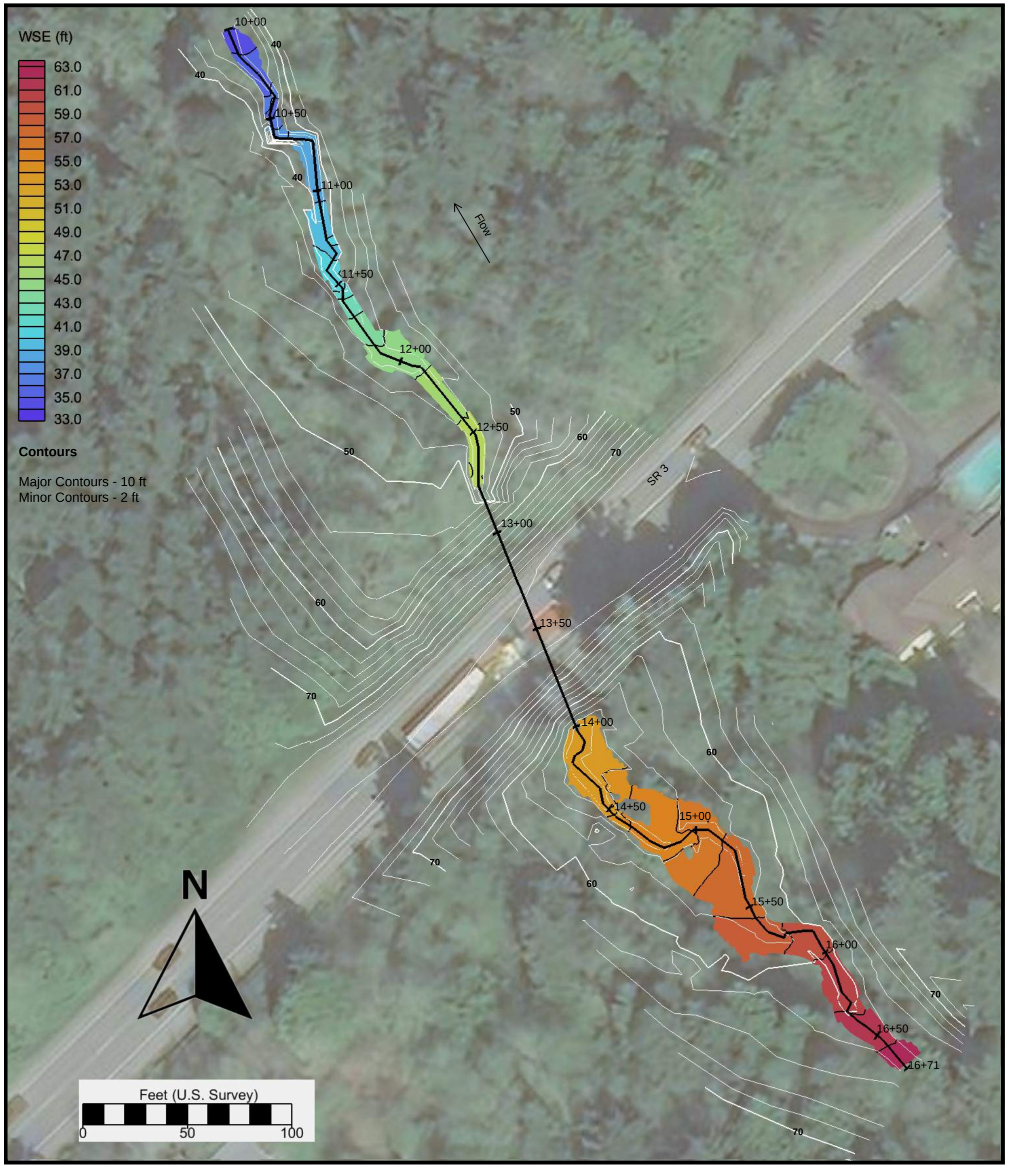


Existing Condition - Q100 Shear Stress* (psf)

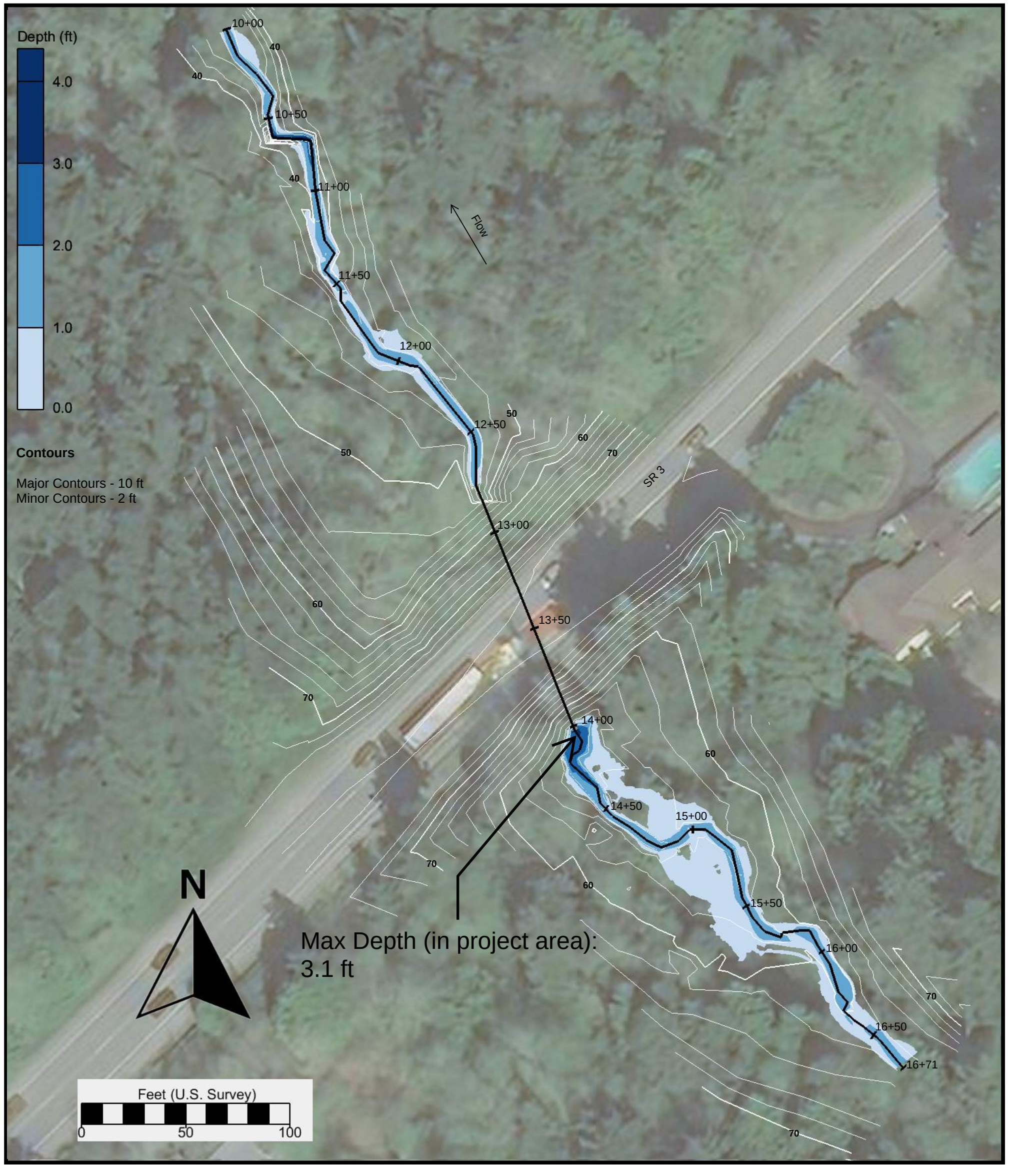


*Shear stress results are artificially elevated at the existing culvert outlet due to the high roughness region used to slow velocity closer to its field expected value and facilitate model stability.

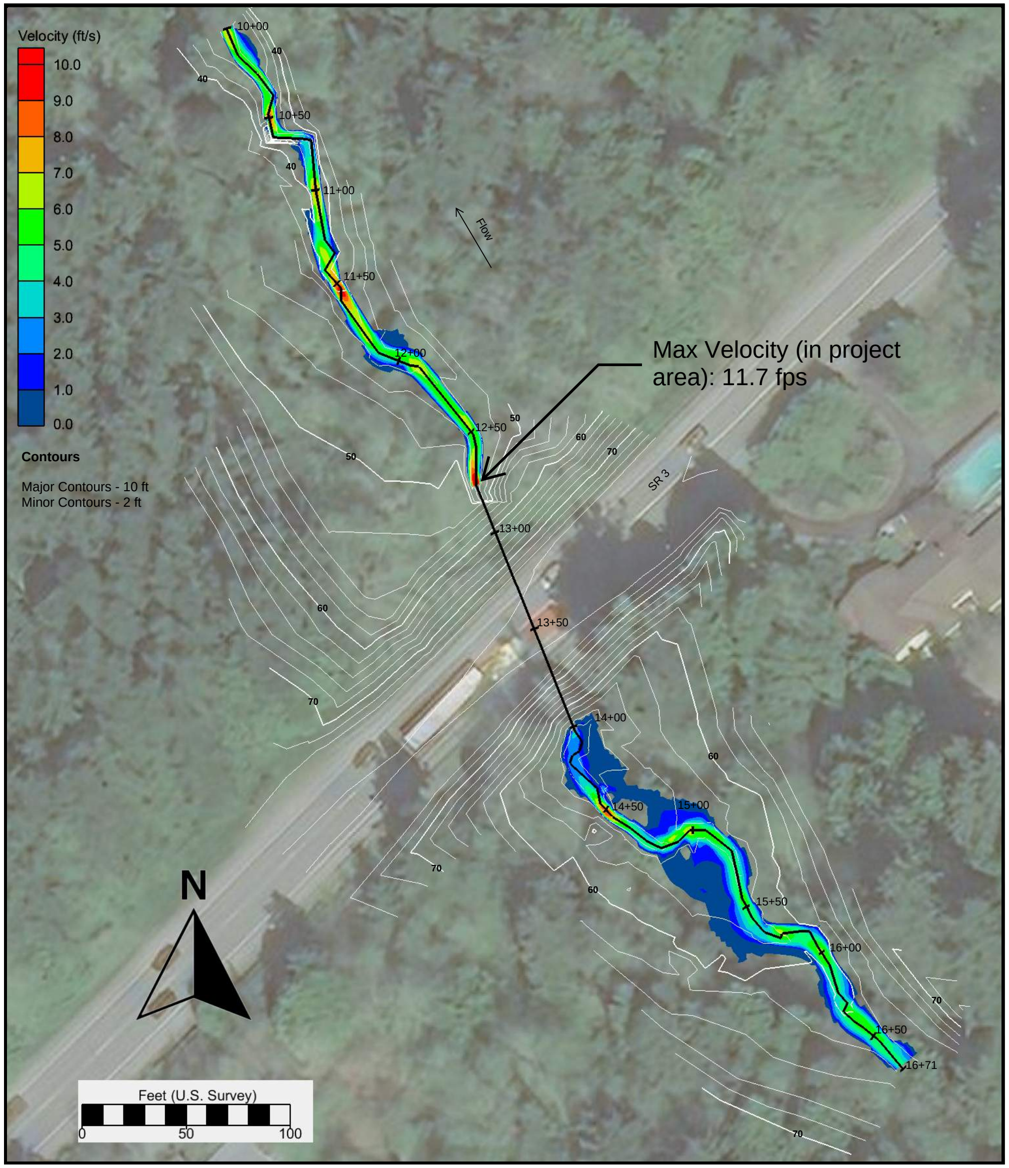
Existing Condition - Q100 WSE (NAVD88) (ft)



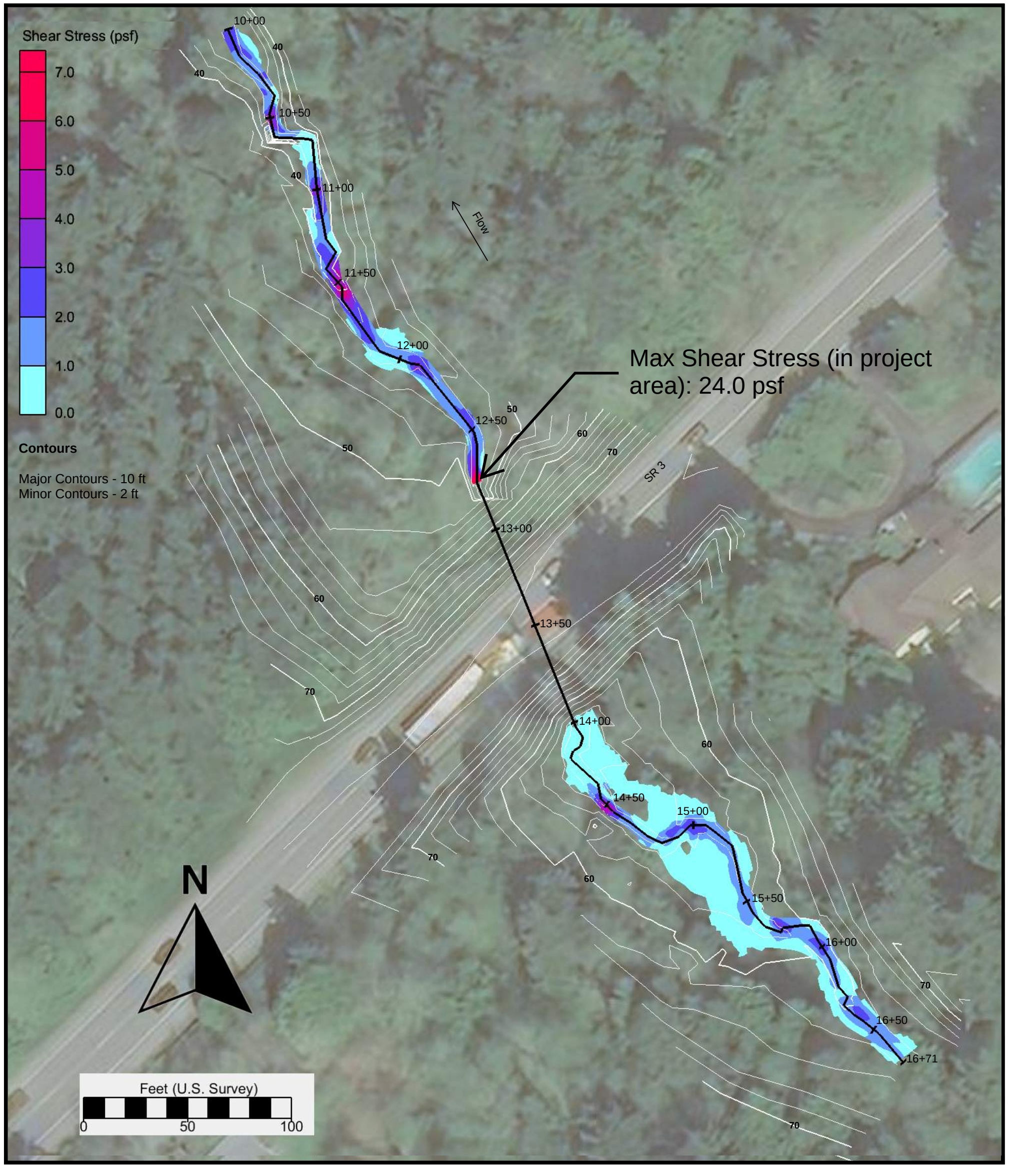
Existing Condition - Q100 Depth (ft)



Existing Condition - Q 500 Velocity (fps)

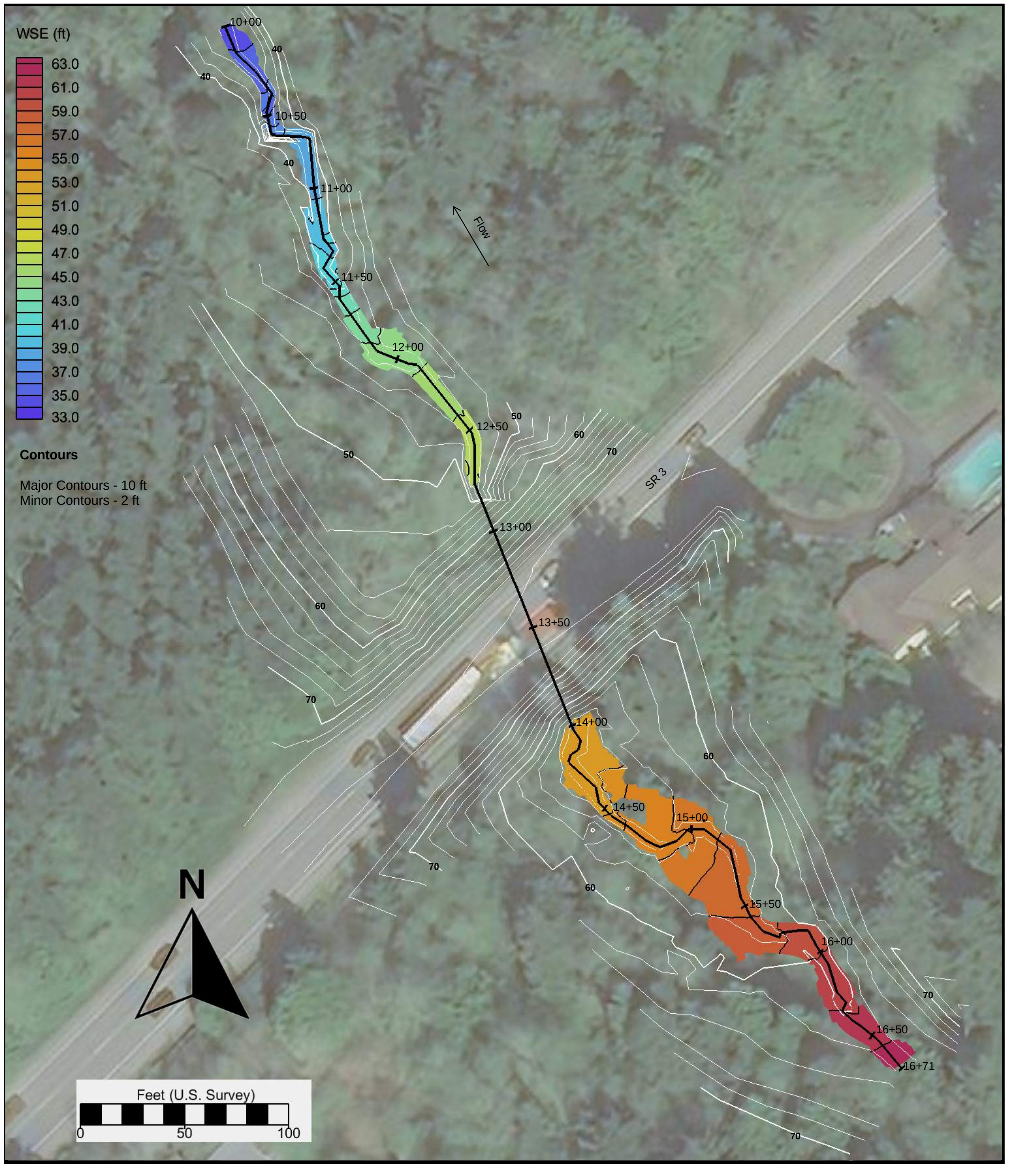


Existing Condition - Q500 Shear Stress* (psf)

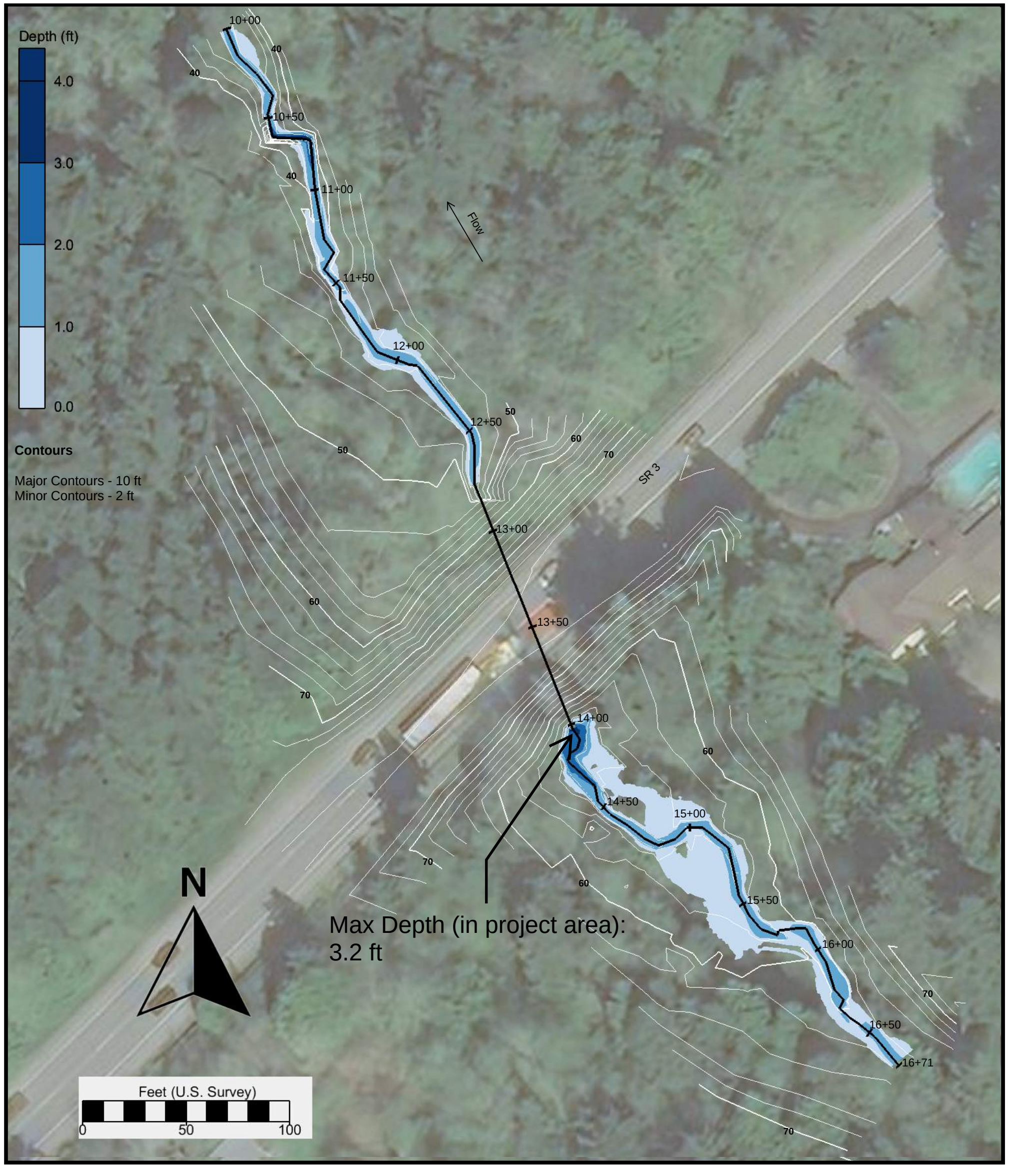


*Shear stress results are artificially elevated at the existing culvert outlet due to the high roughness region used to slow velocity closer to its field expected value and facilitate model stability.

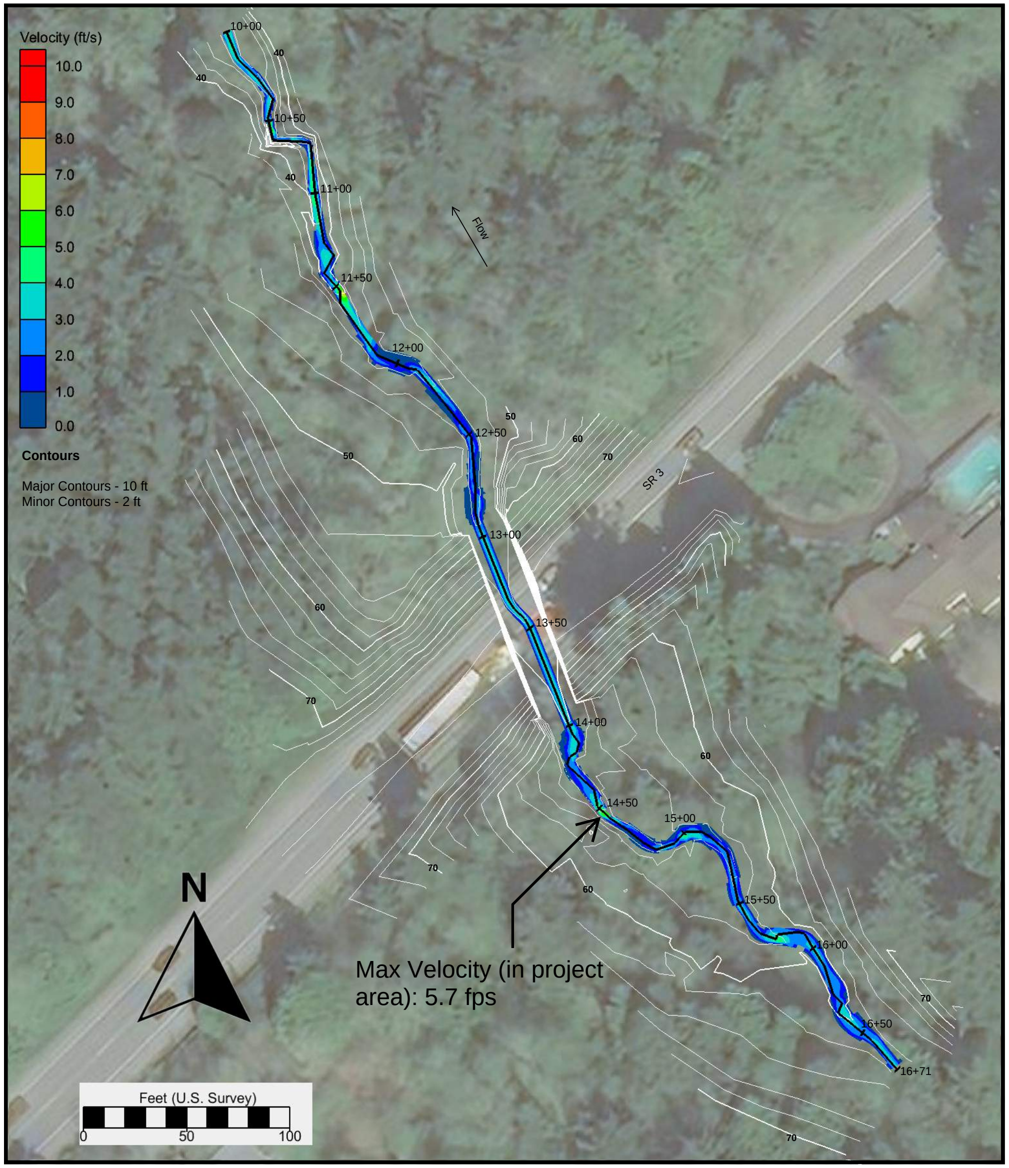
Existing Condition - Q500 WSE (NAVD88) (ft)



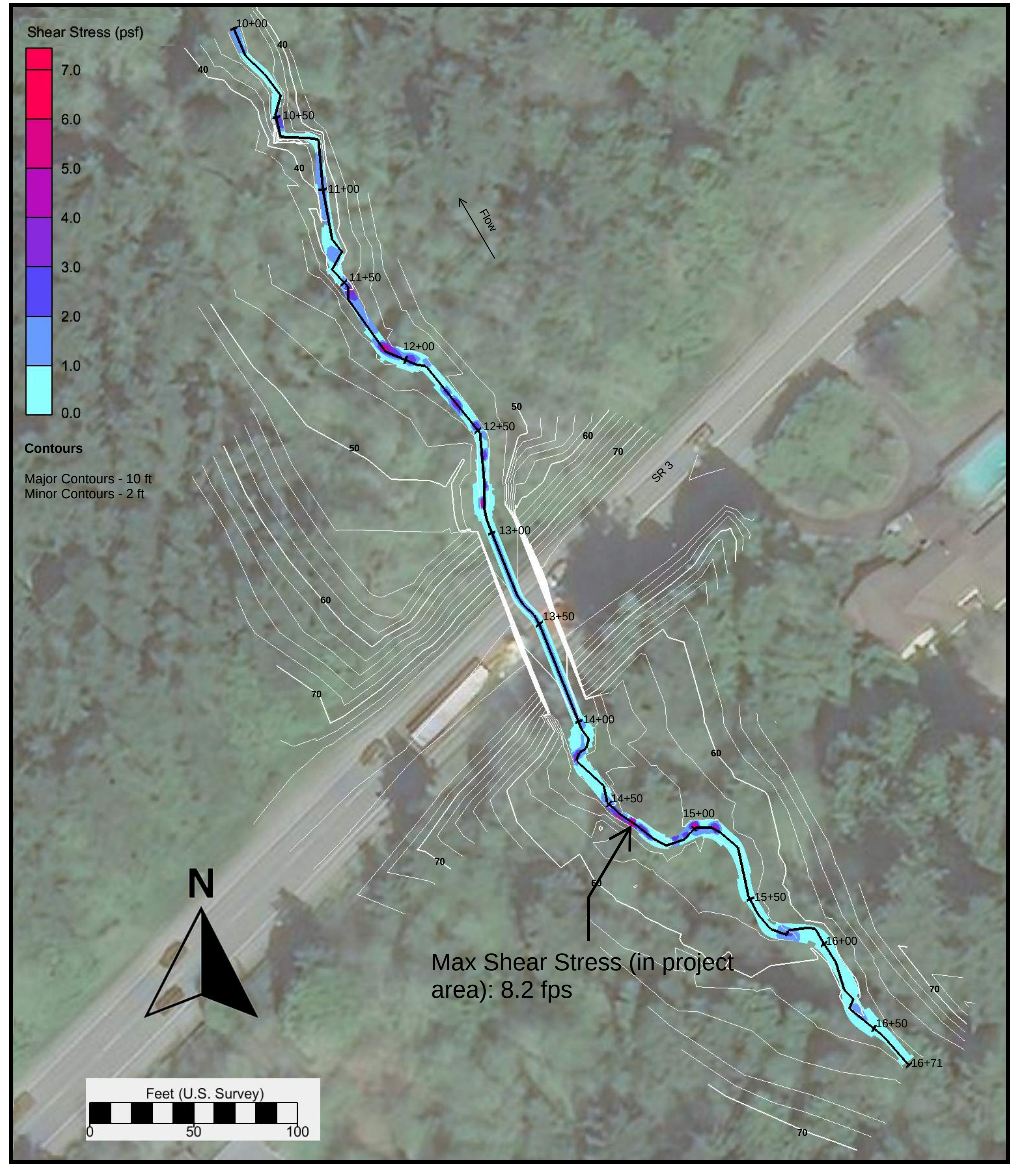
Existing Condition - Q500 Depth (ft)



Proposed Condition - Q2 Velocity (fps)

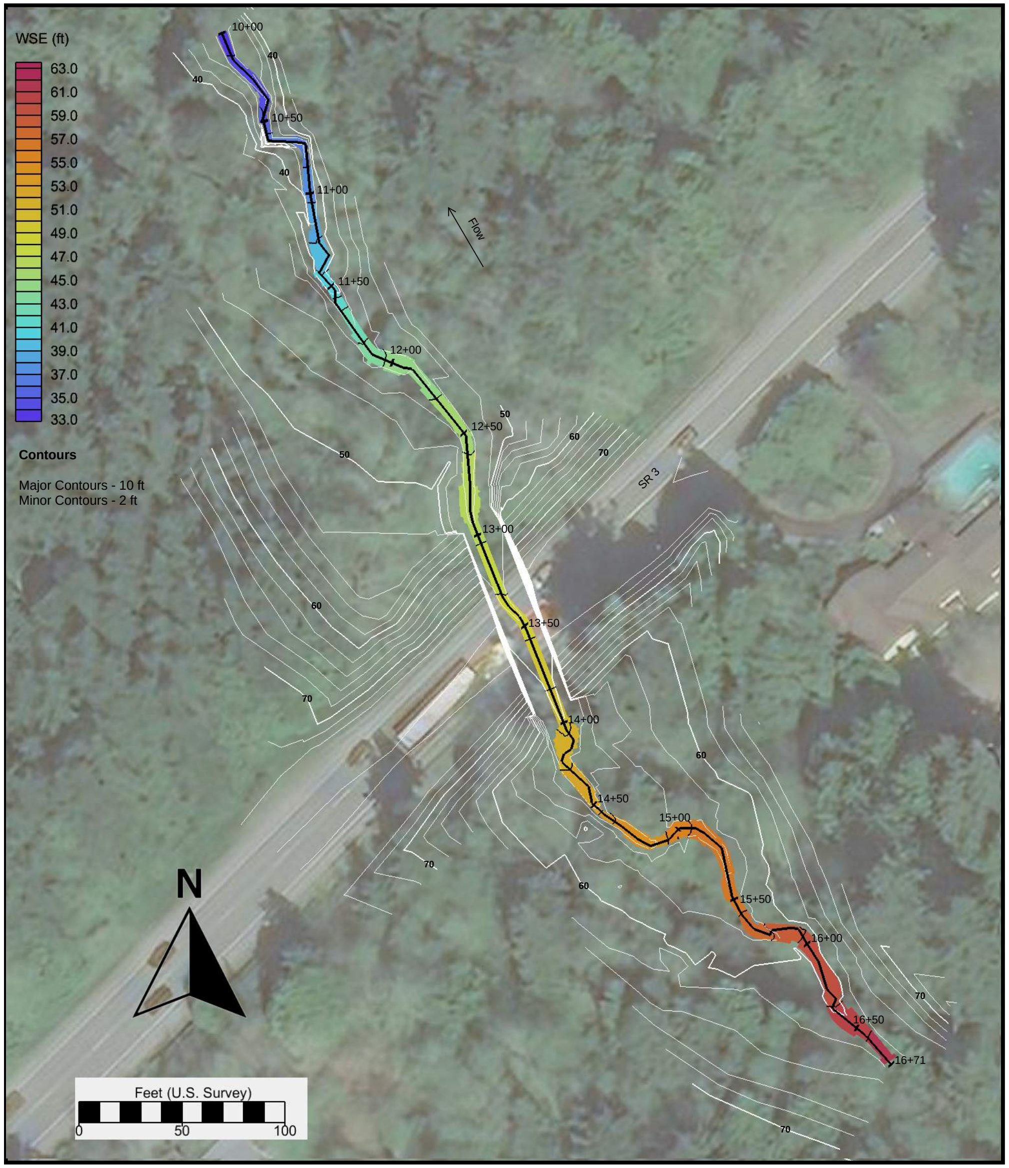


Proposed Condition - Q2 Shear Stress* (psf)

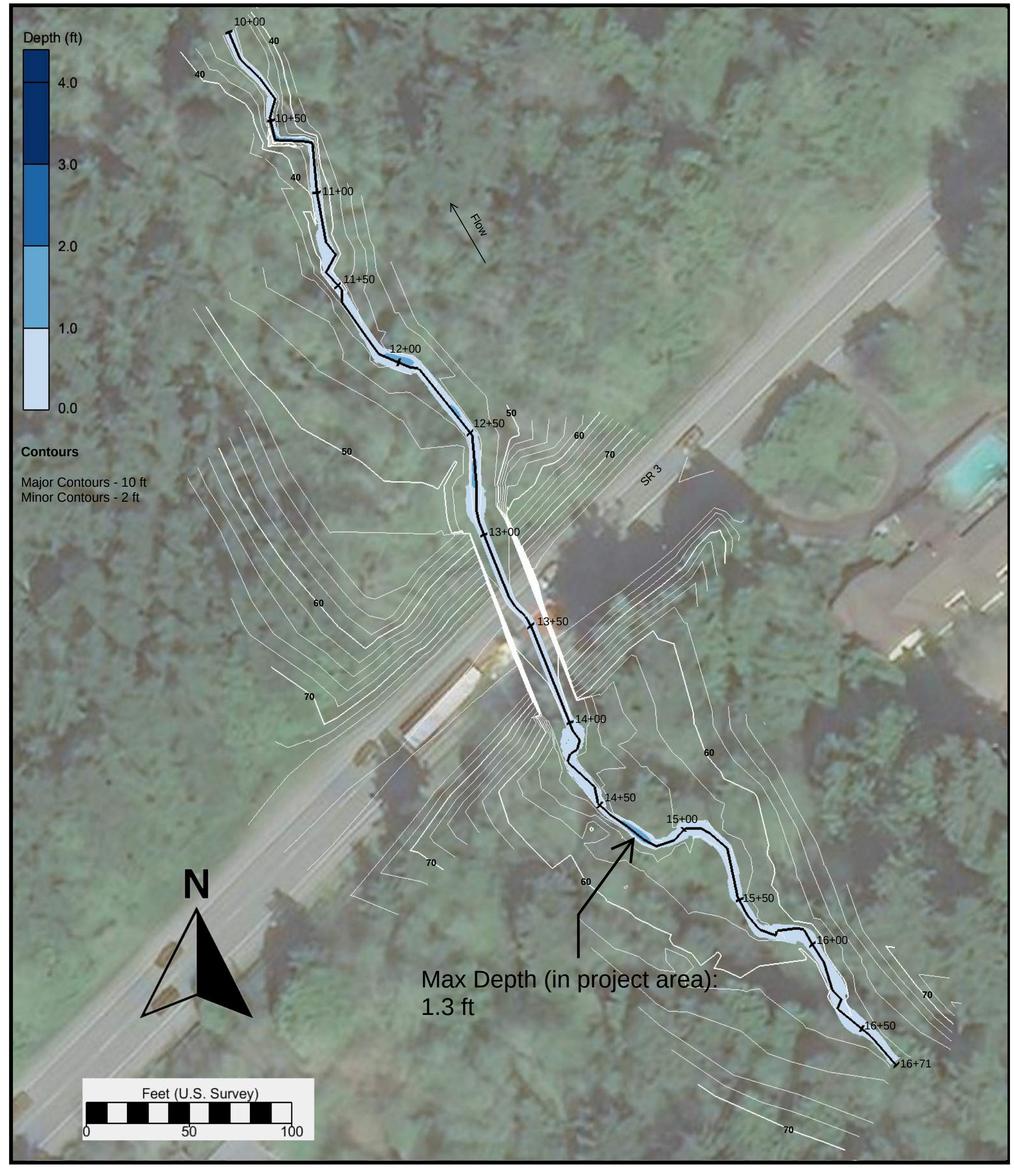


*Shear stress results are artificially elevated near the proposed LWM due to the discrete high roughness regions used to represent those structures in the model.

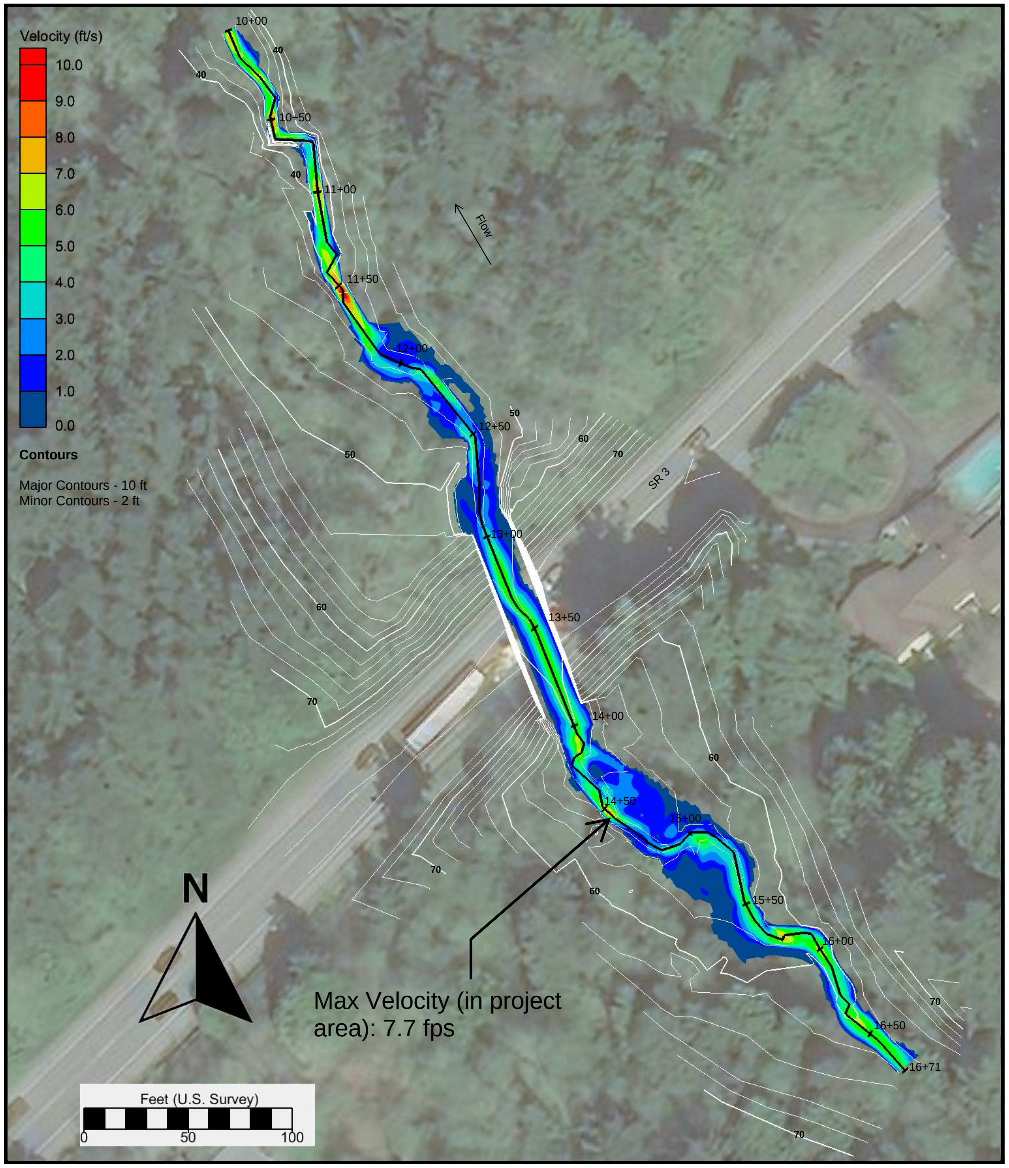
Proposed Condition - Q2 WSE (NAVD88) (ft)



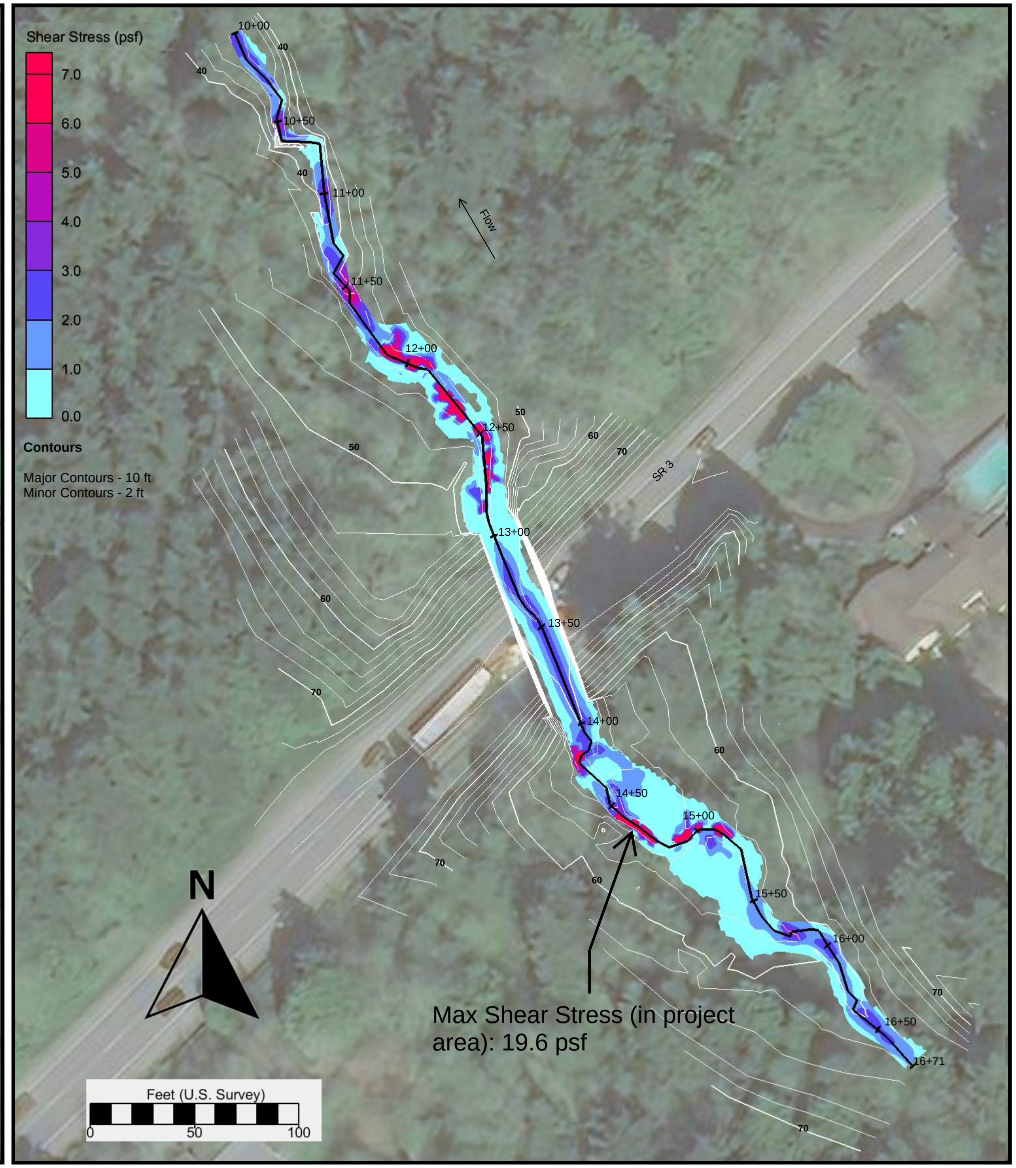
Proposed Condition - Q2 Depth (ft)



Proposed Condition - Q100 Velocity (fps)

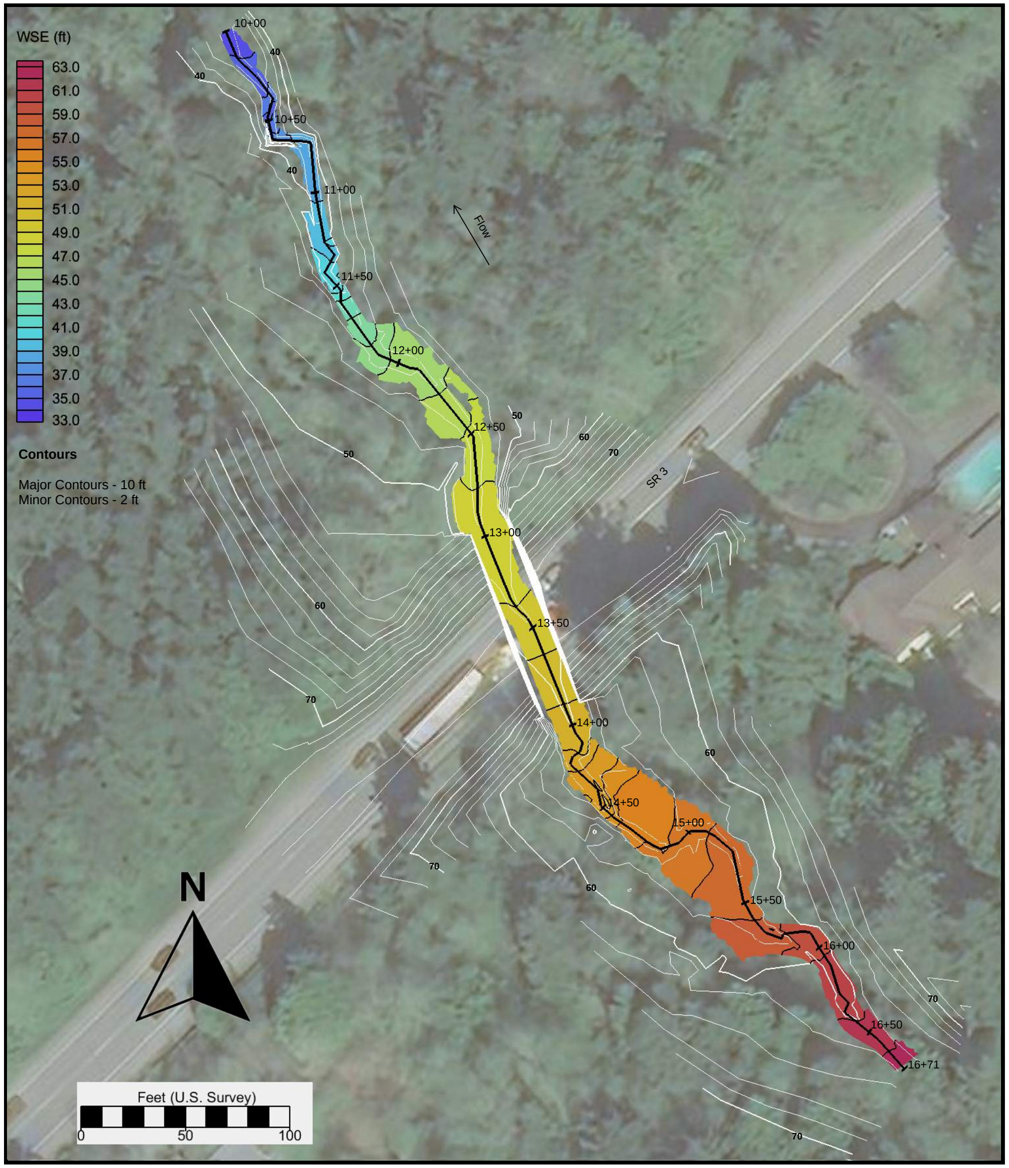


Proposed Condition - Q100 Shear Stress* (psf)

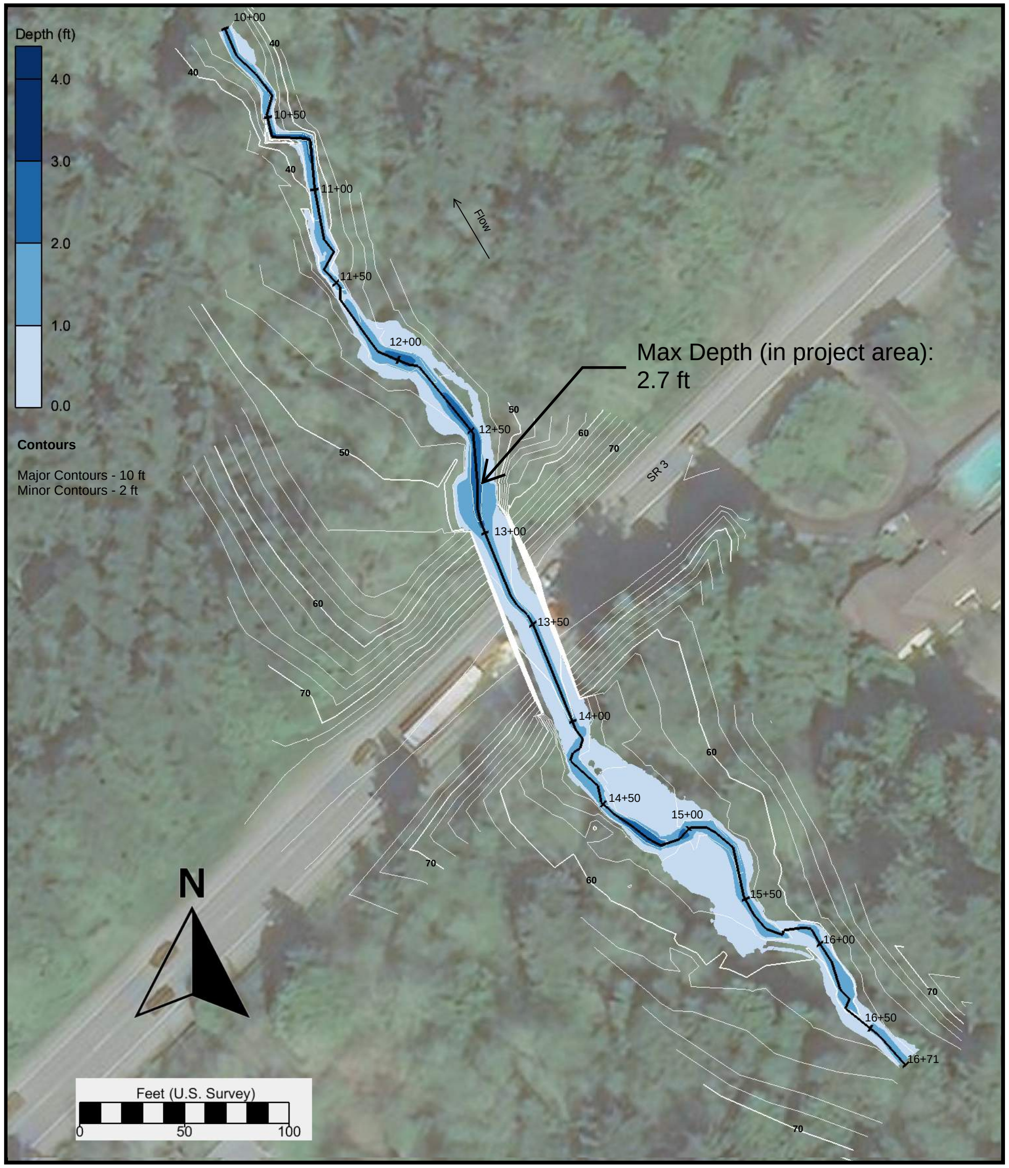


*Shear stress results are artificially elevated near the proposed LWM due to the discrete high roughness regions used to represent those structures in the model.

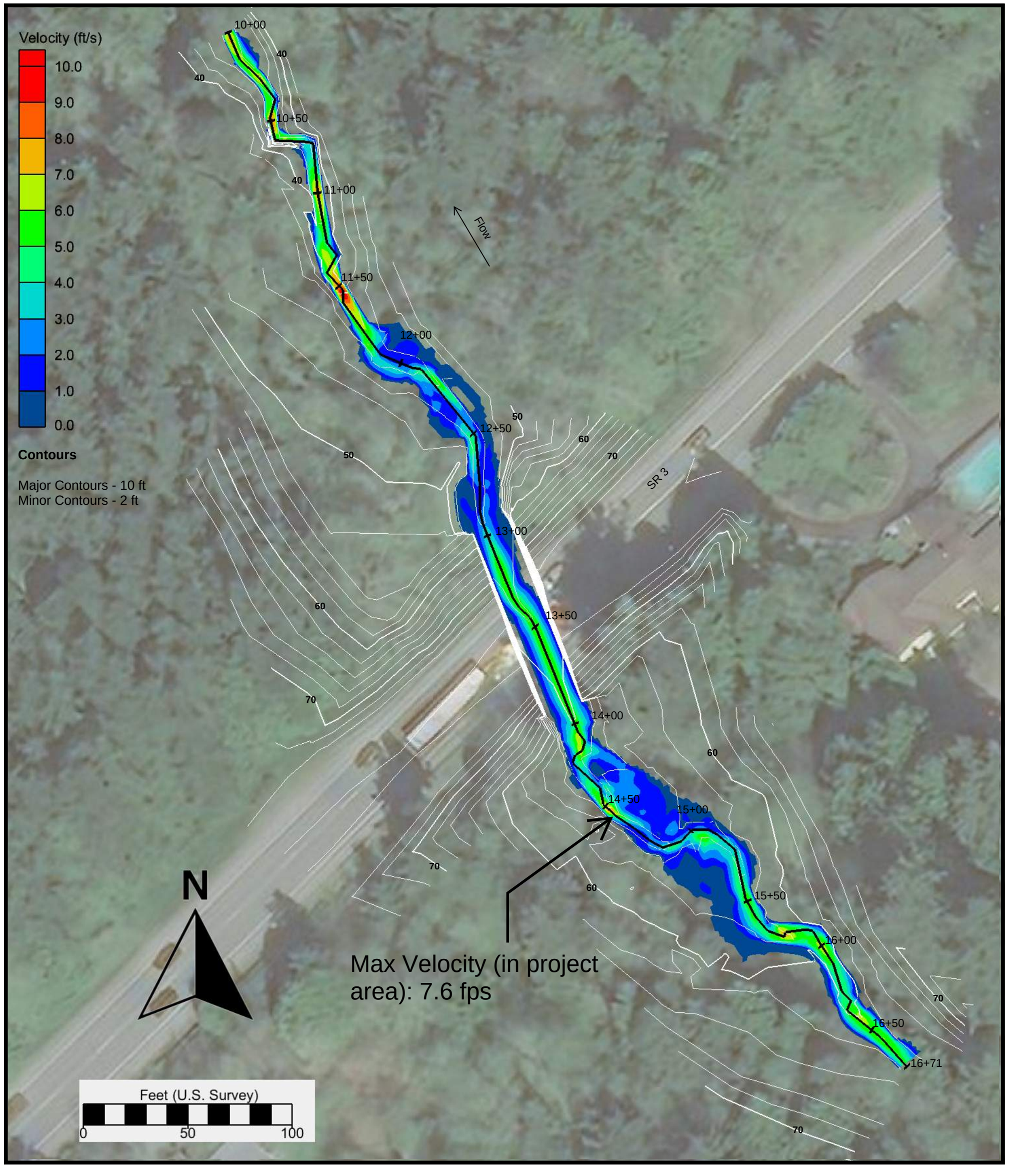
Proposed Condition - Q100 WSE (NAVD88) (ft)



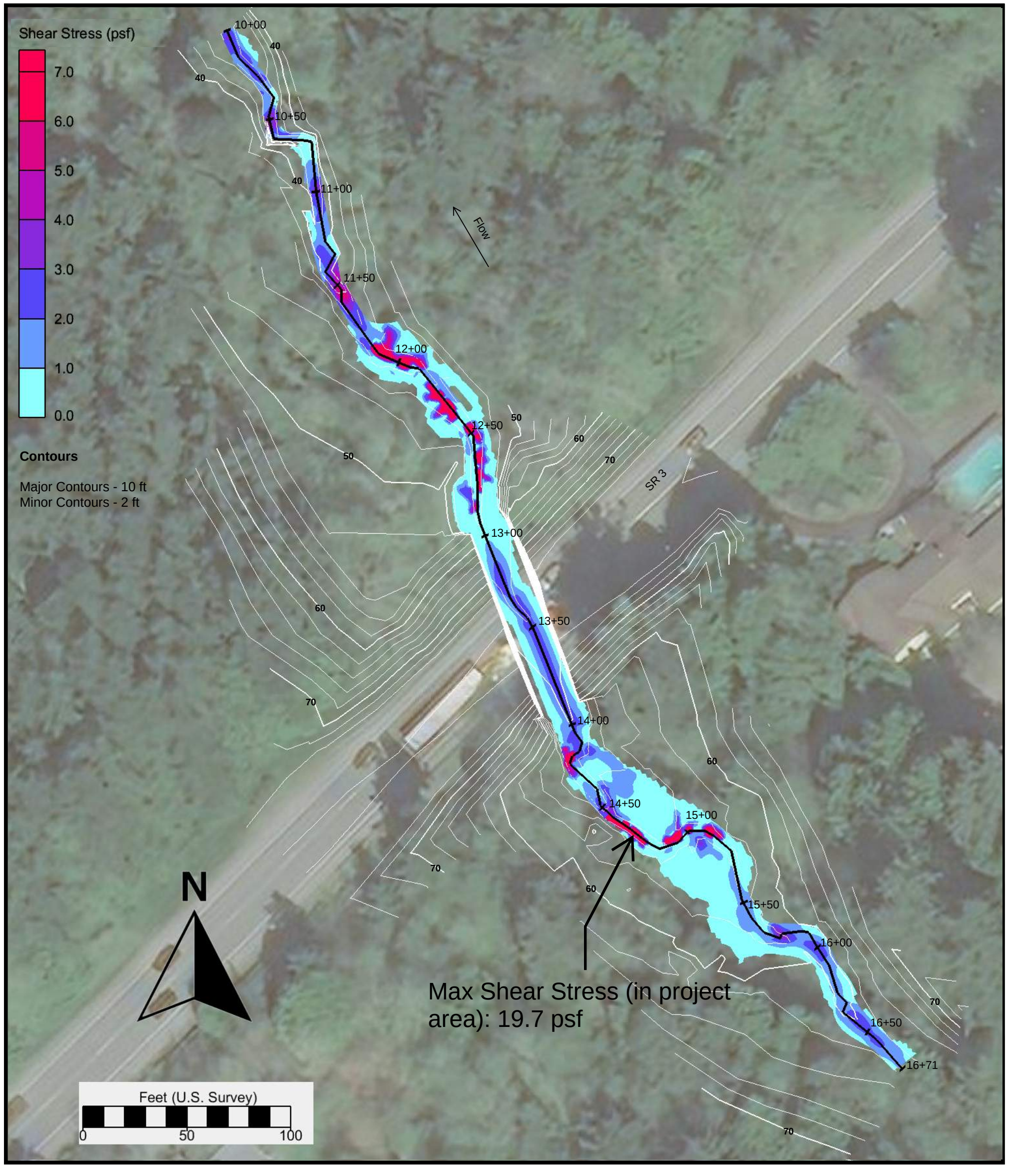
Proposed Condition - Q100 Depth (ft)



Proposed Condition - Q500 Velocity (fps)

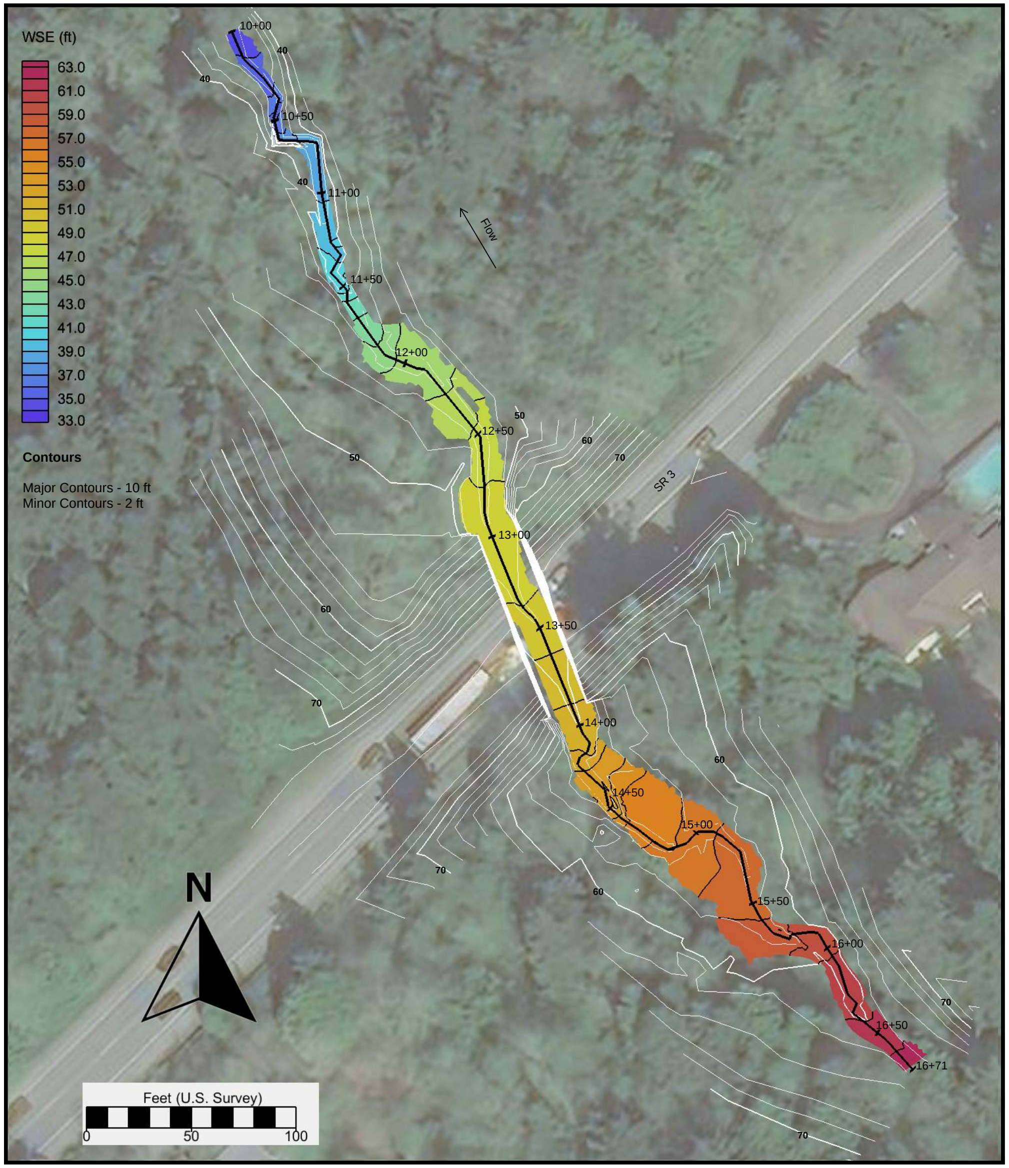


Proposed Condition - Q500 Shear Stress* (psf)

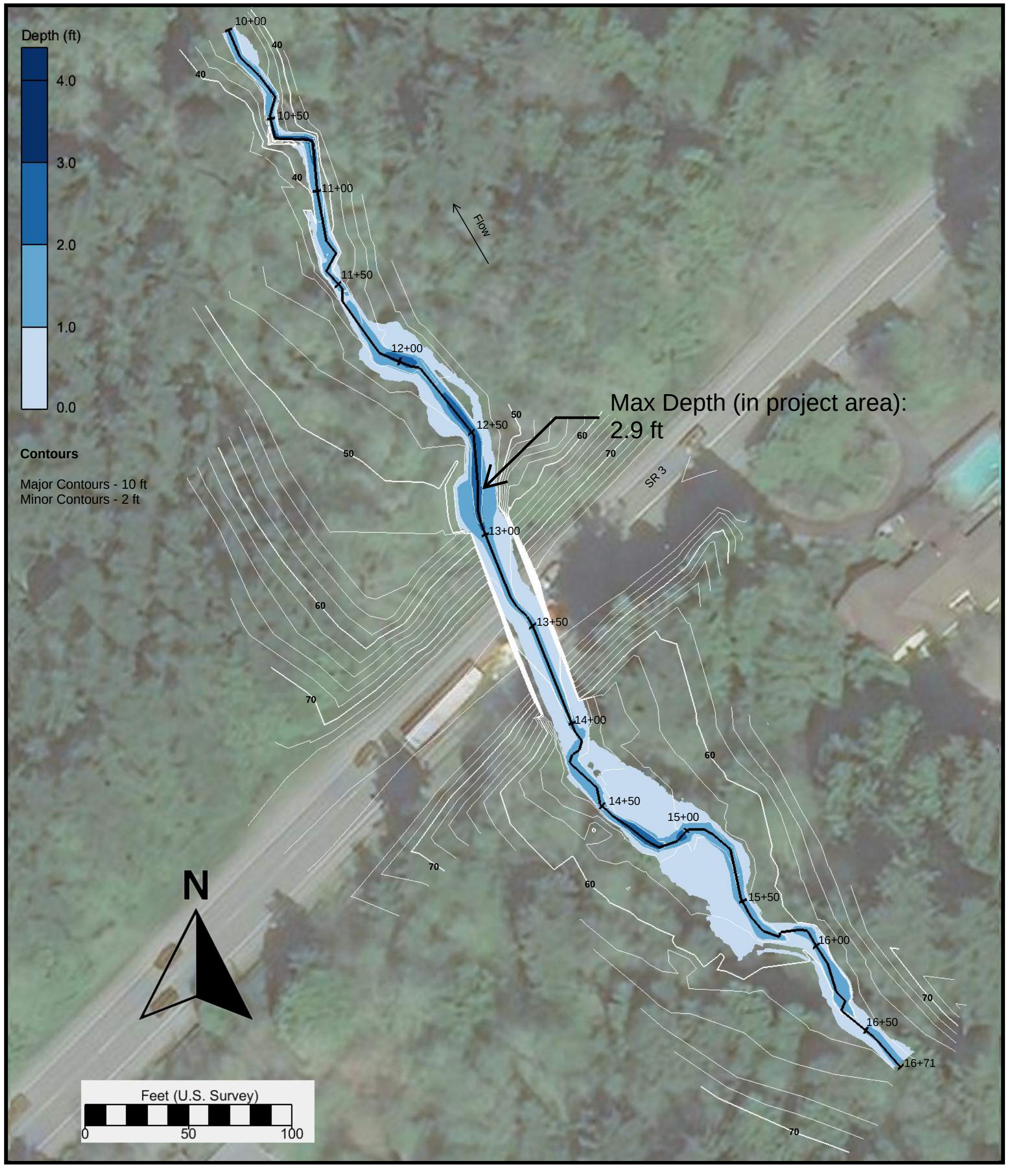


*Shear stress results are artificially elevated near the proposed LWM due to the discrete high roughness regions used to represent those structures in the model.

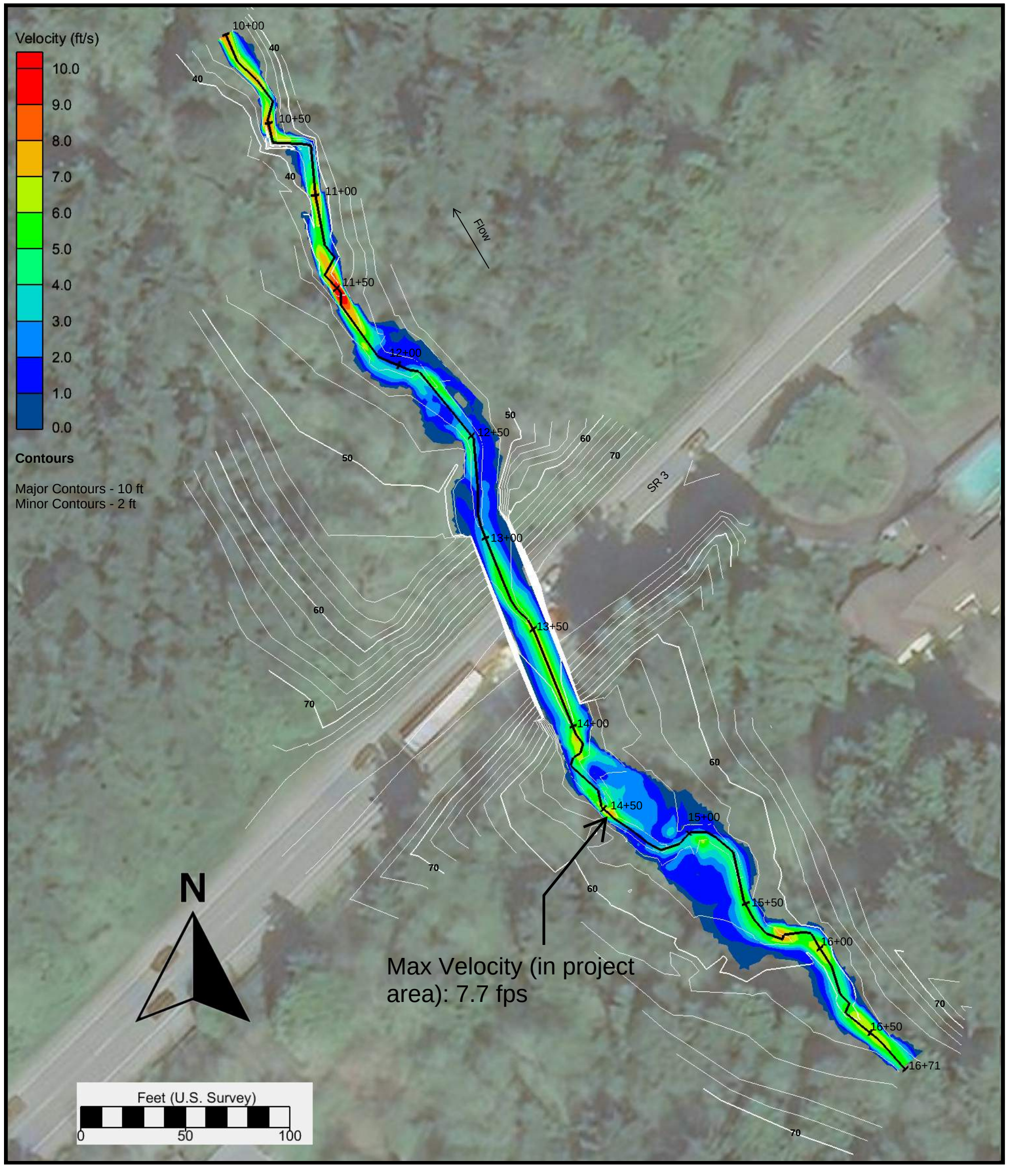
Proposed Condition - Q500 WSE (NAVD88) (ft)



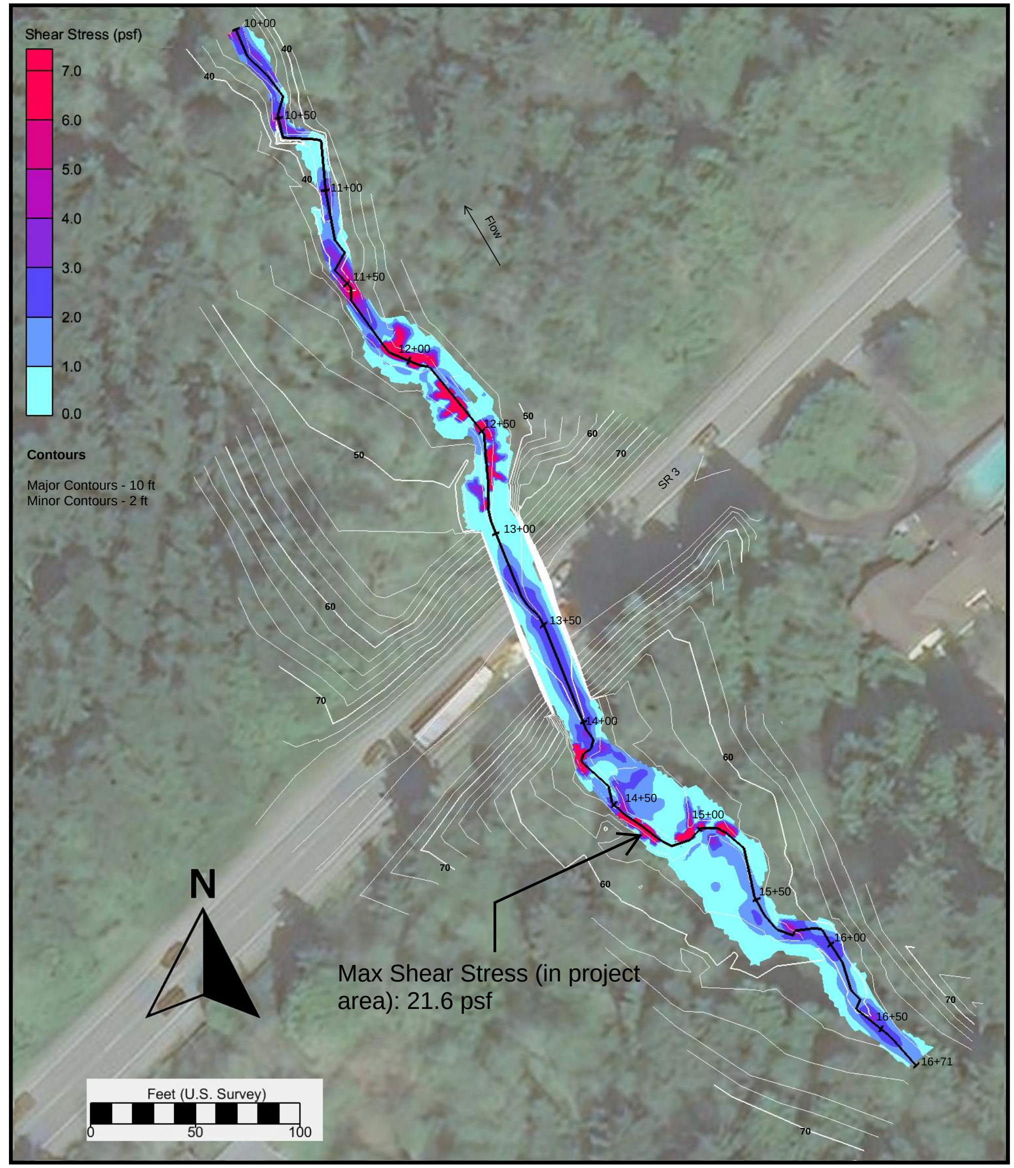
Proposed Condition - Q500 Depth (ft)



Proposed Condition - Projected 2080, Q100 Velocity (fps)

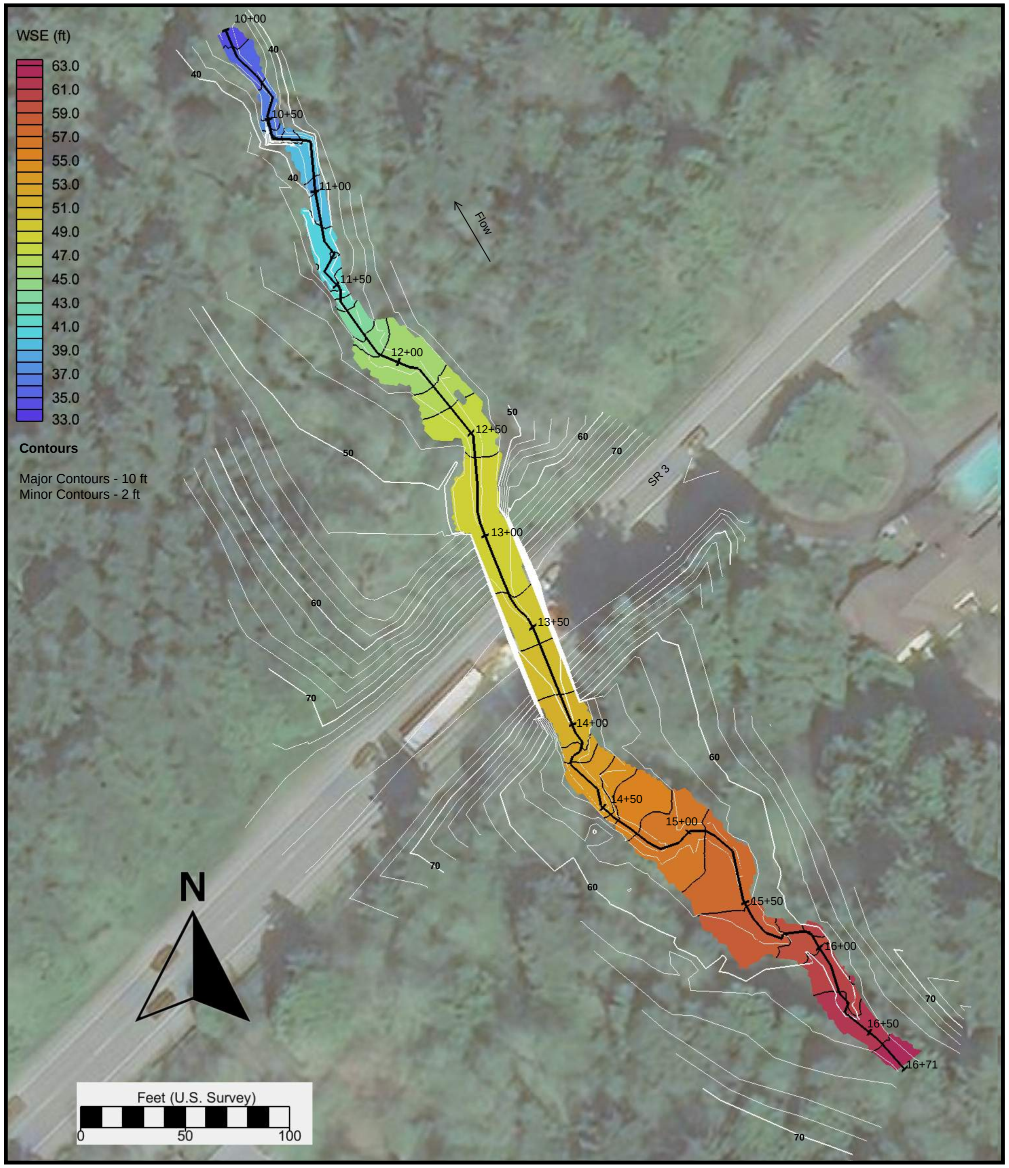


Proposed Condition - Projected 2080, Q100 Shear Stress* (psf)

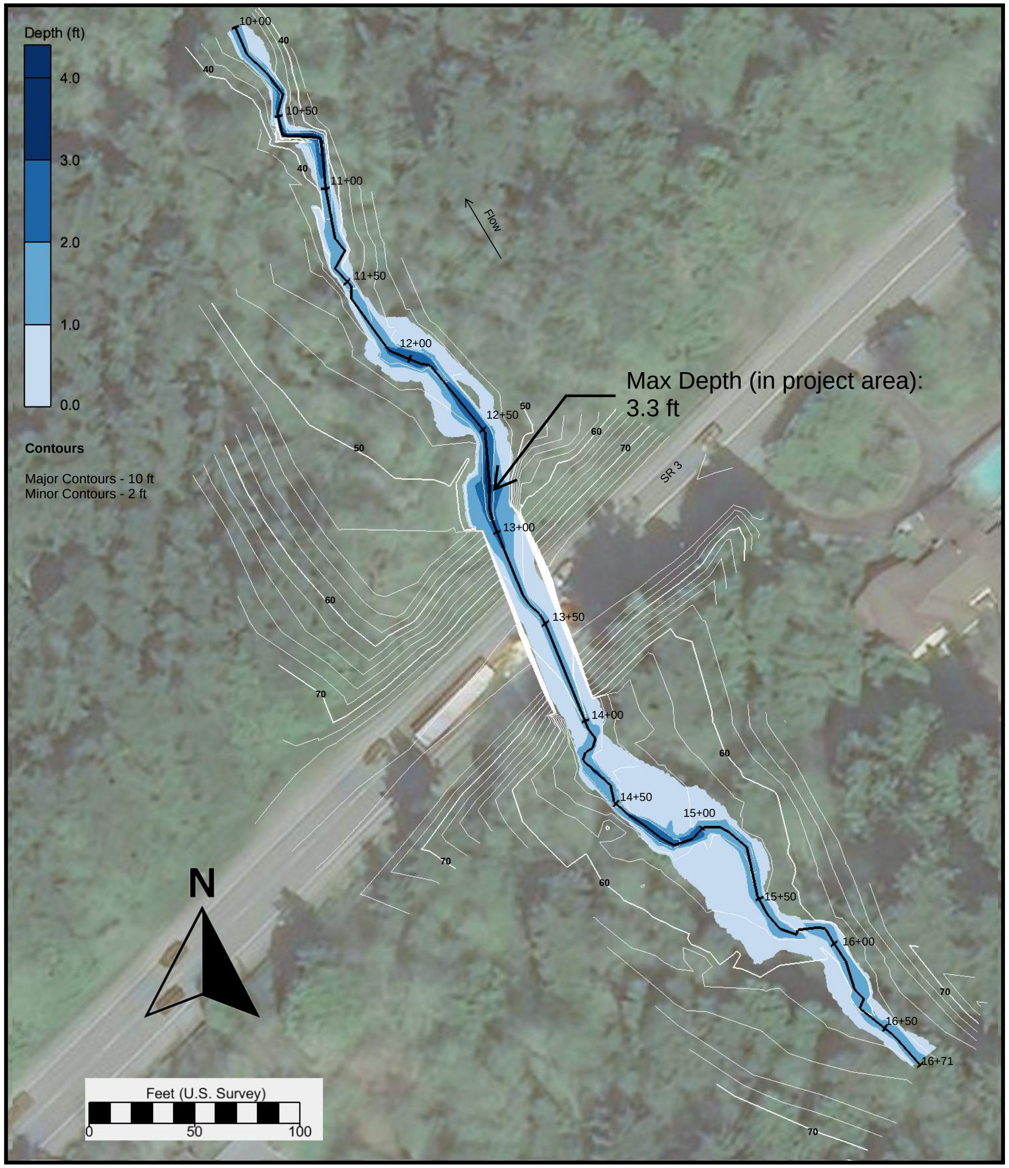


*Shear stress results are artificially elevated near the proposed LWM due to the discrete high roughness regions used to represent those structures in the model.

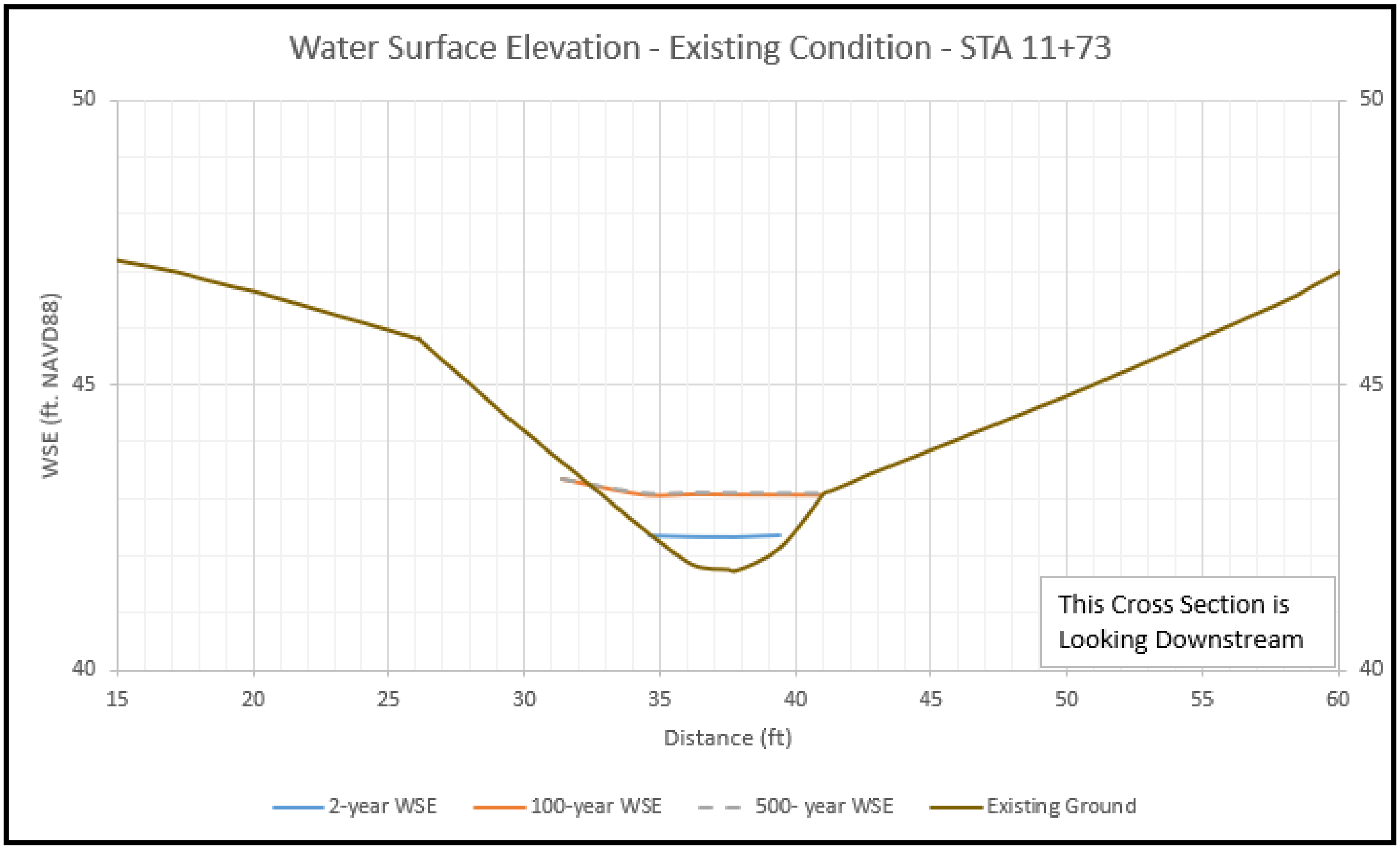
Proposed Condition - Projected 2080, Q100 WSE (NAVD88) (ft)



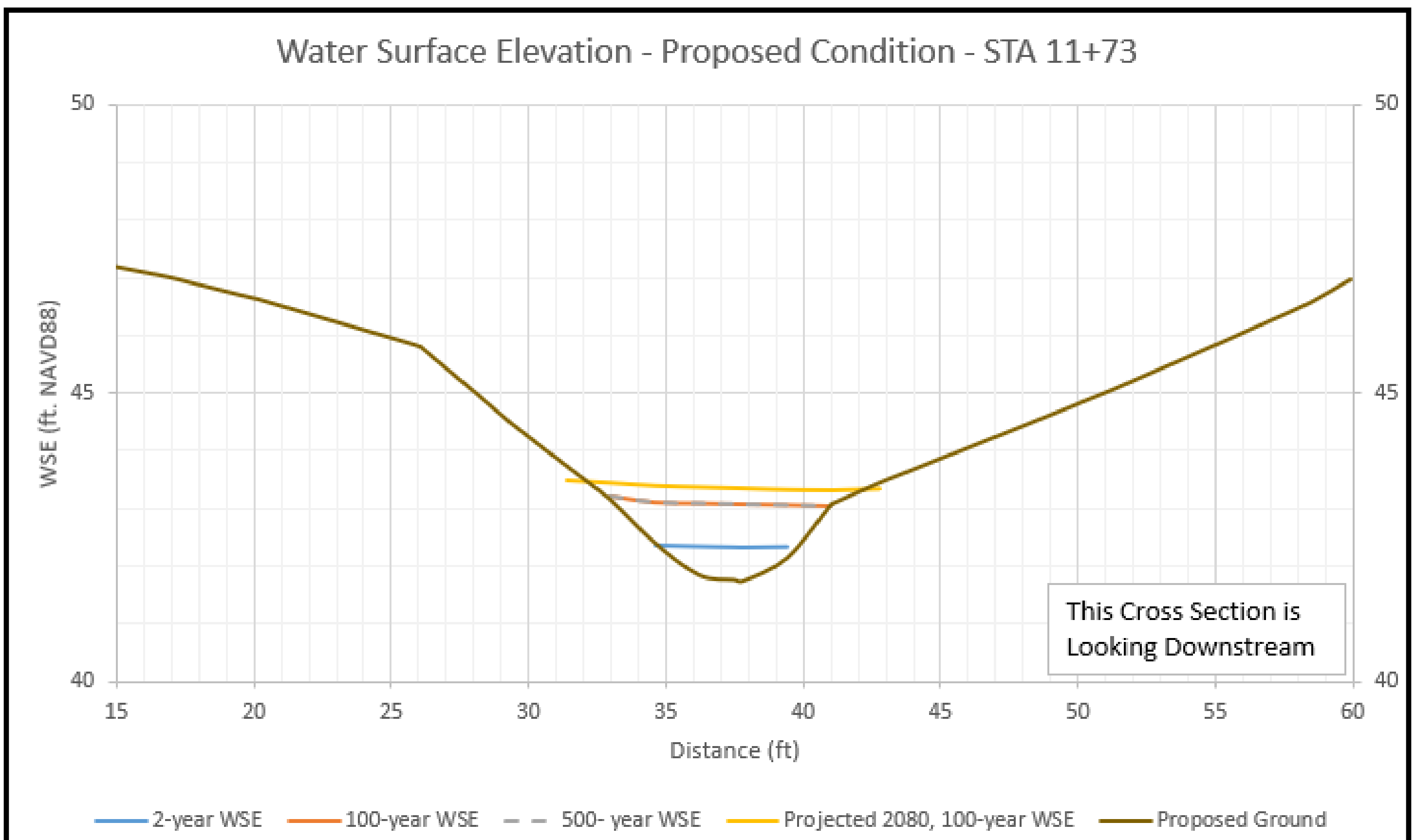
Proposed Condition - Projected 2080, Q100 Depth (ft)



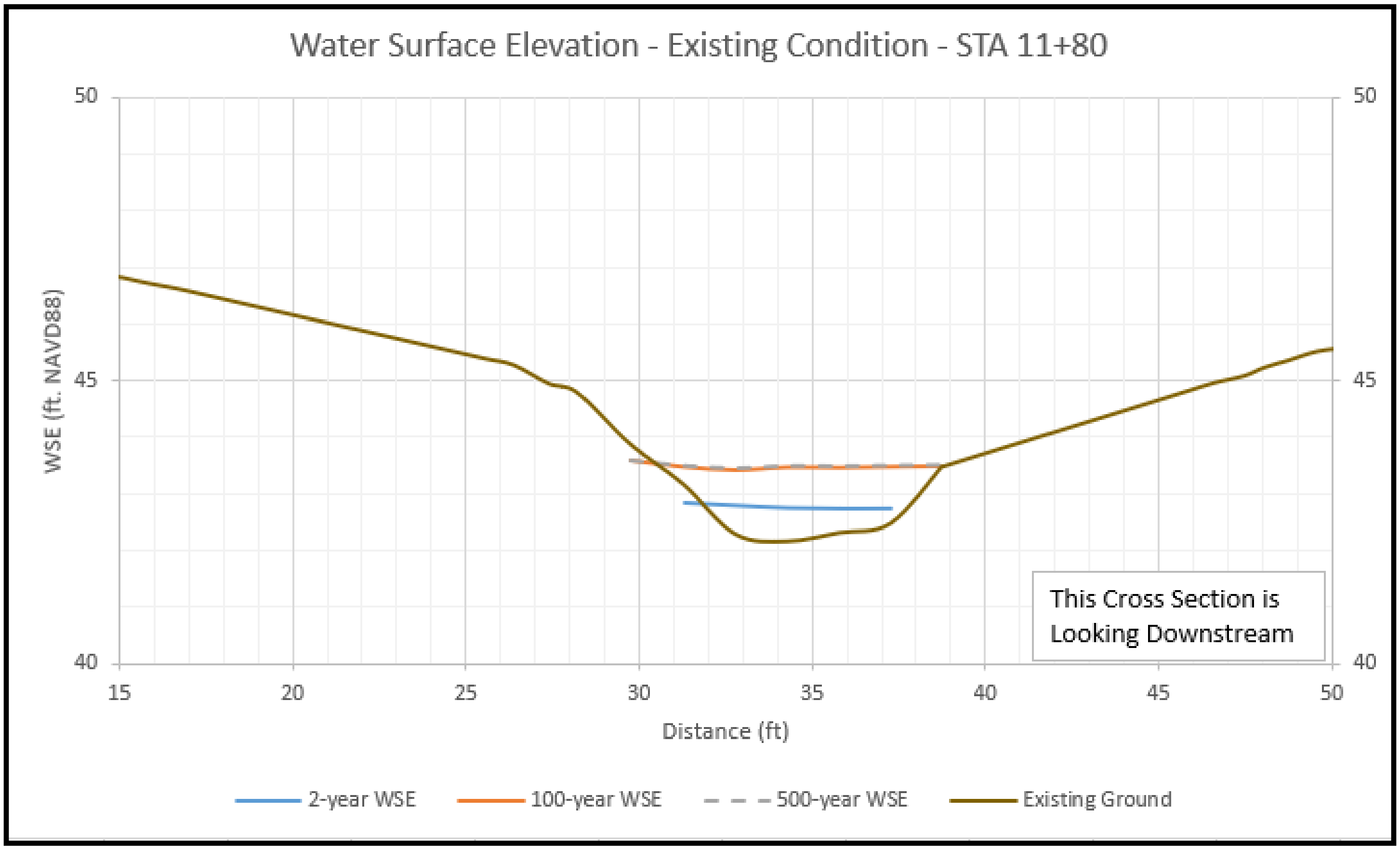
Existing Condition Cross Section — Station 11+73



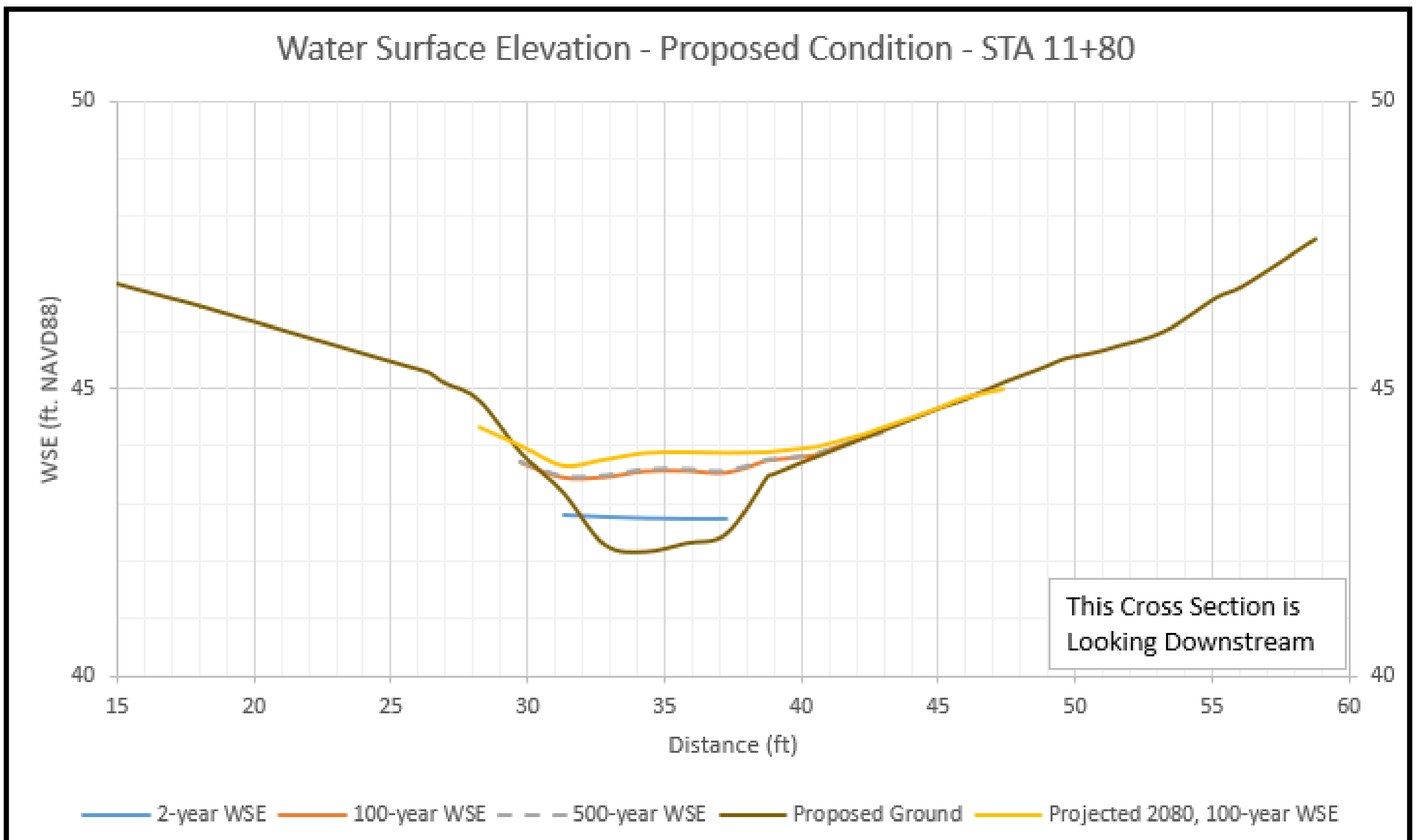
Proposed Condition Cross Section — Station 11+73



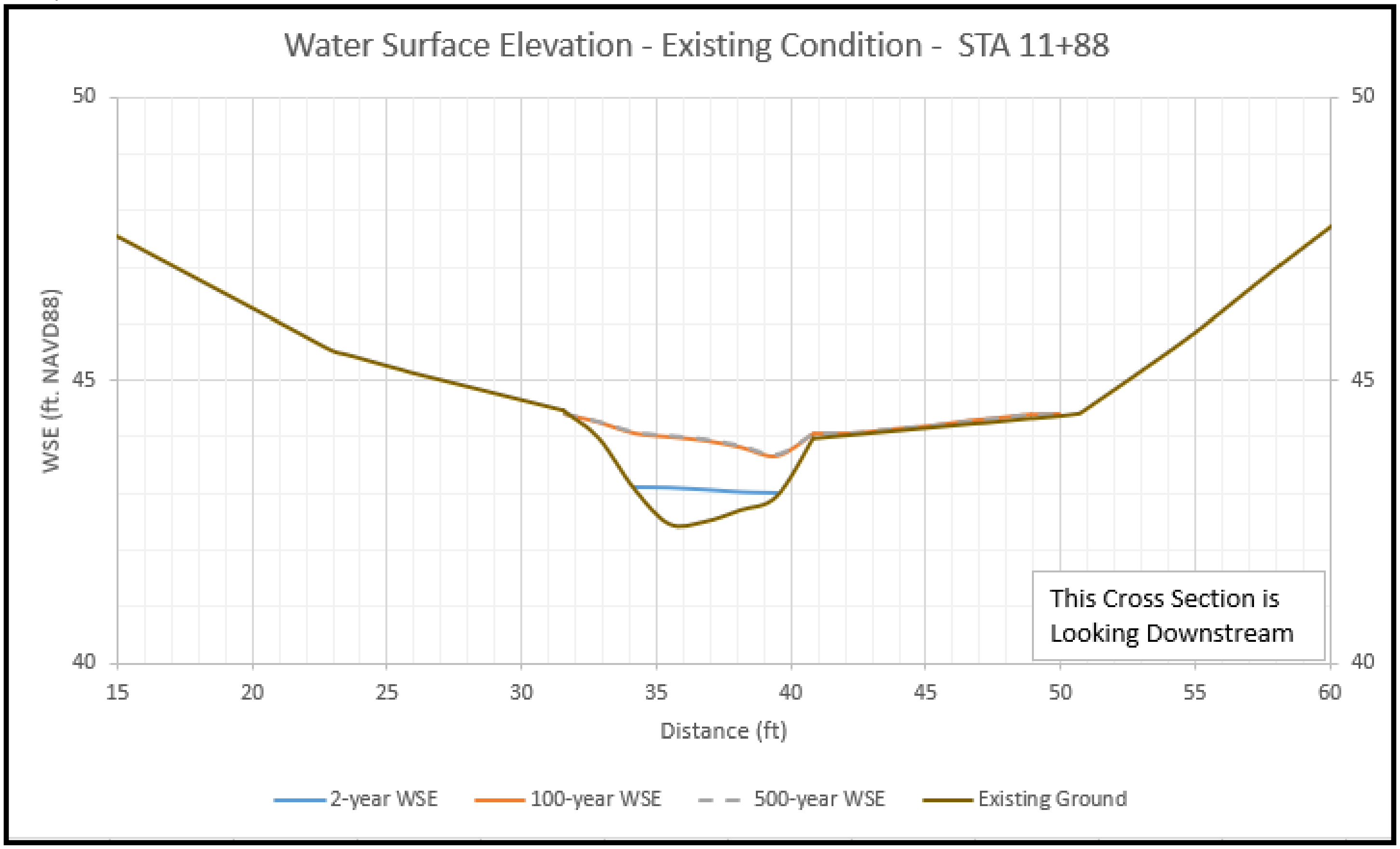
Existing Condition Cross Section — Station 11+80



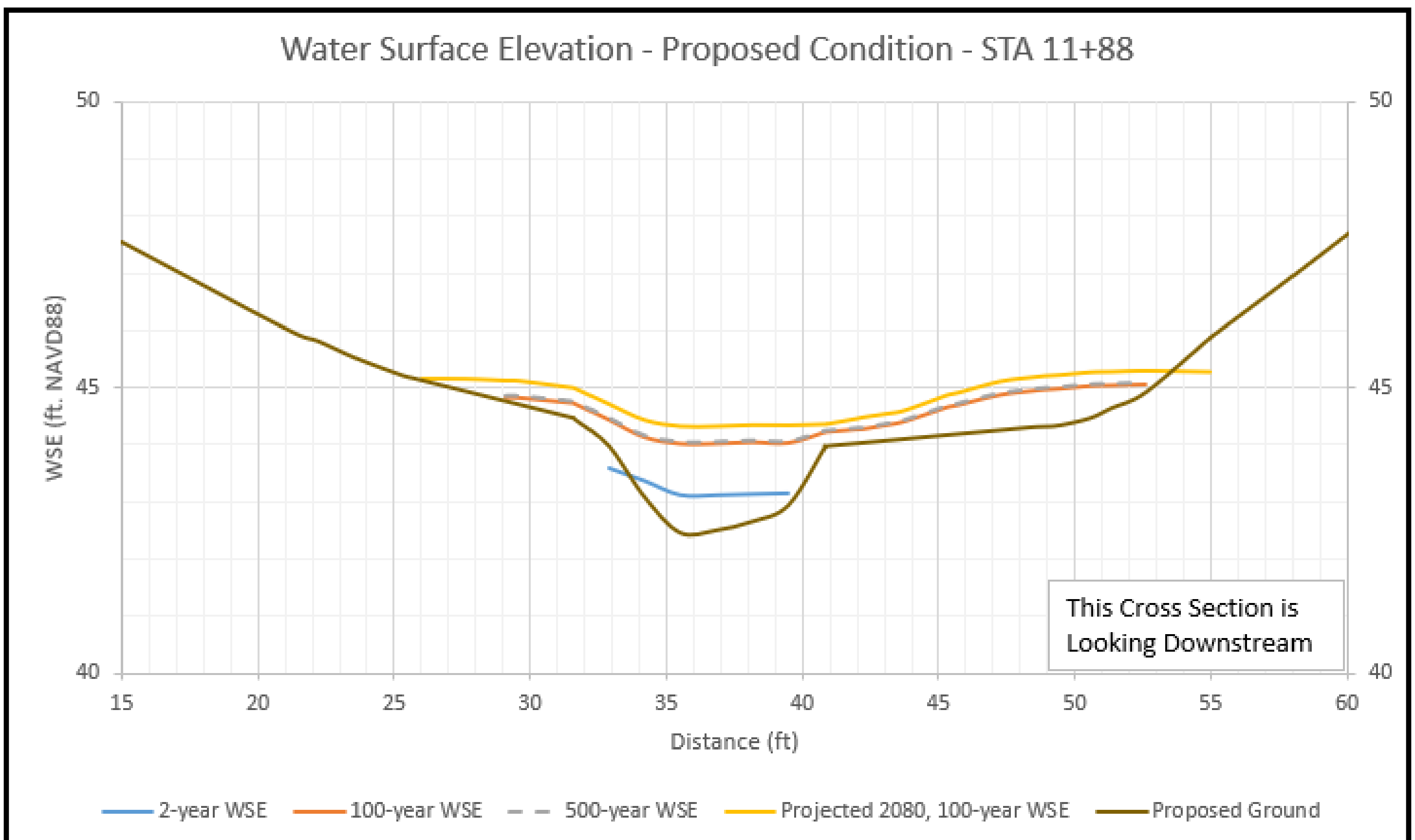
Proposed Condition Cross Section — Station 11+80



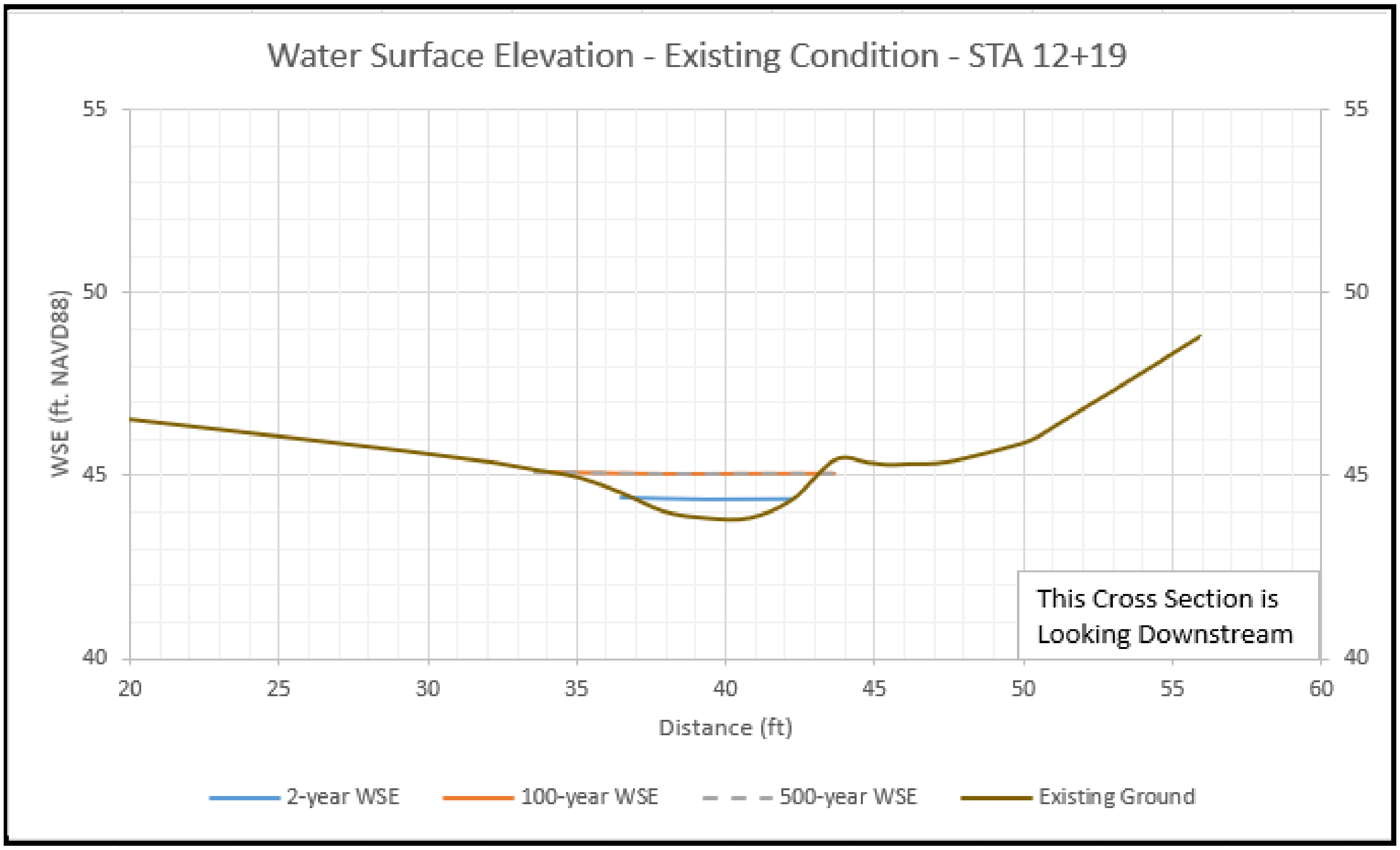
Proposed Condition Cross Section — Station 11+88



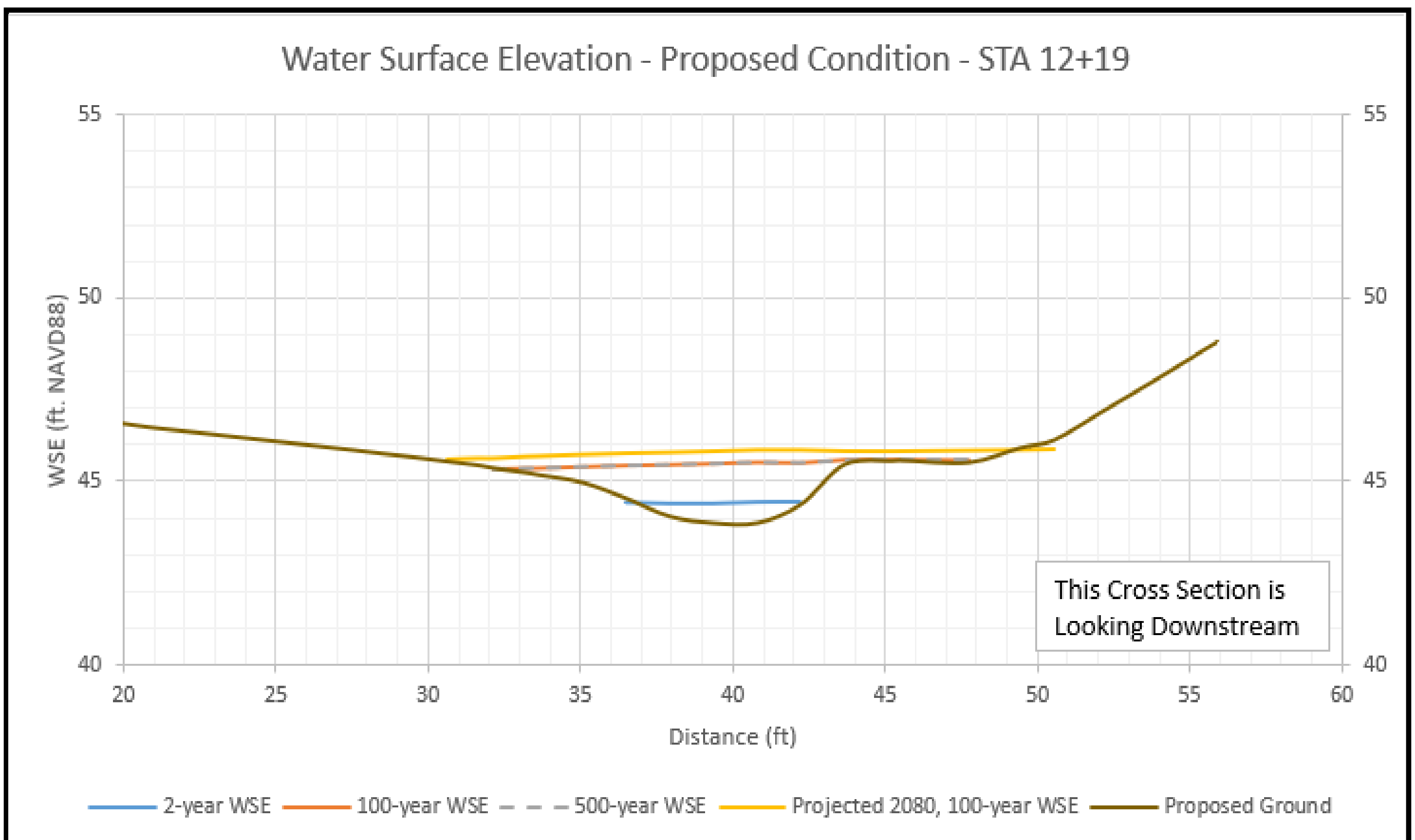
Proposed Condition Cross Section — Station 11+88



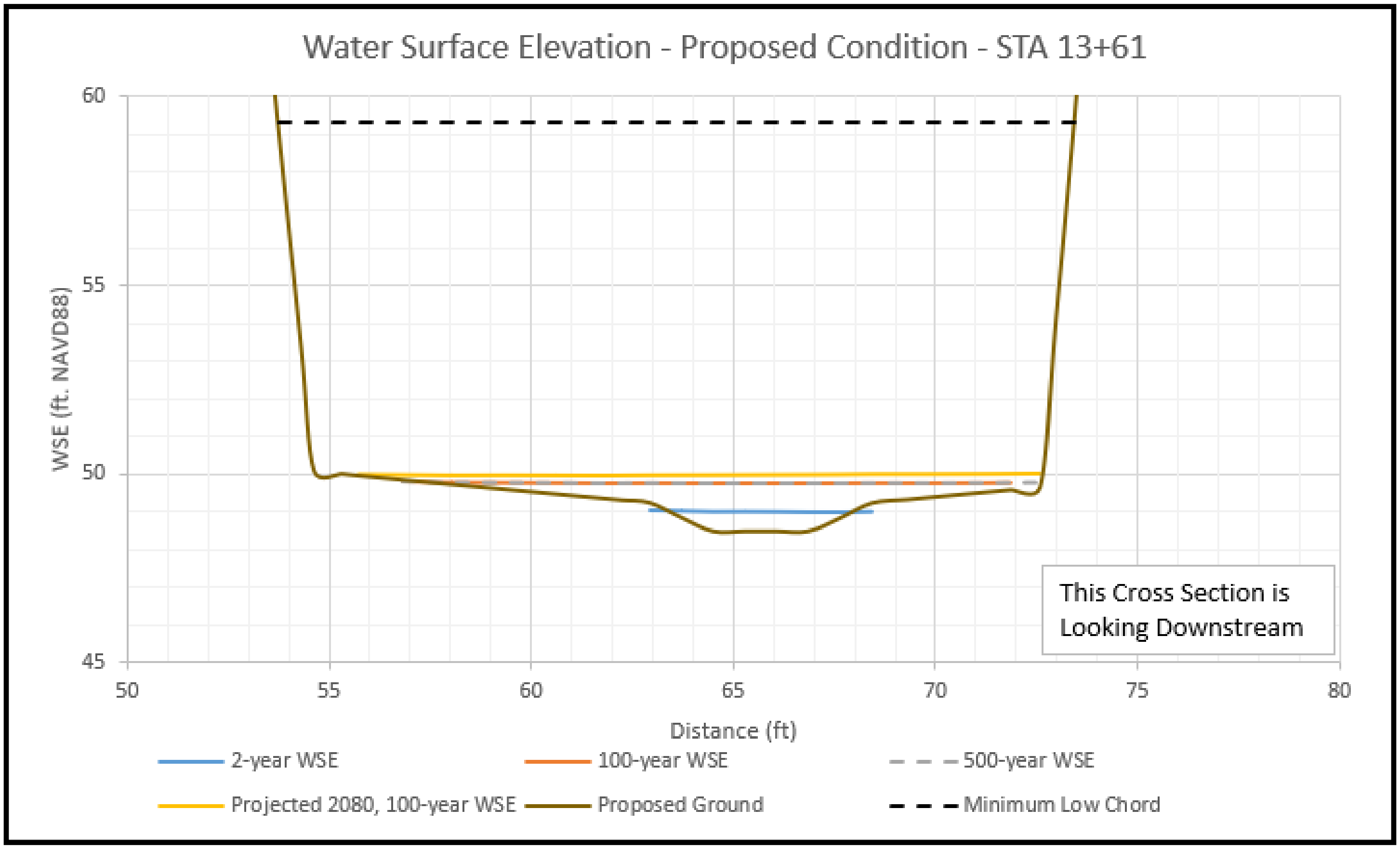
Existing Condition Cross Section — Station 12+19



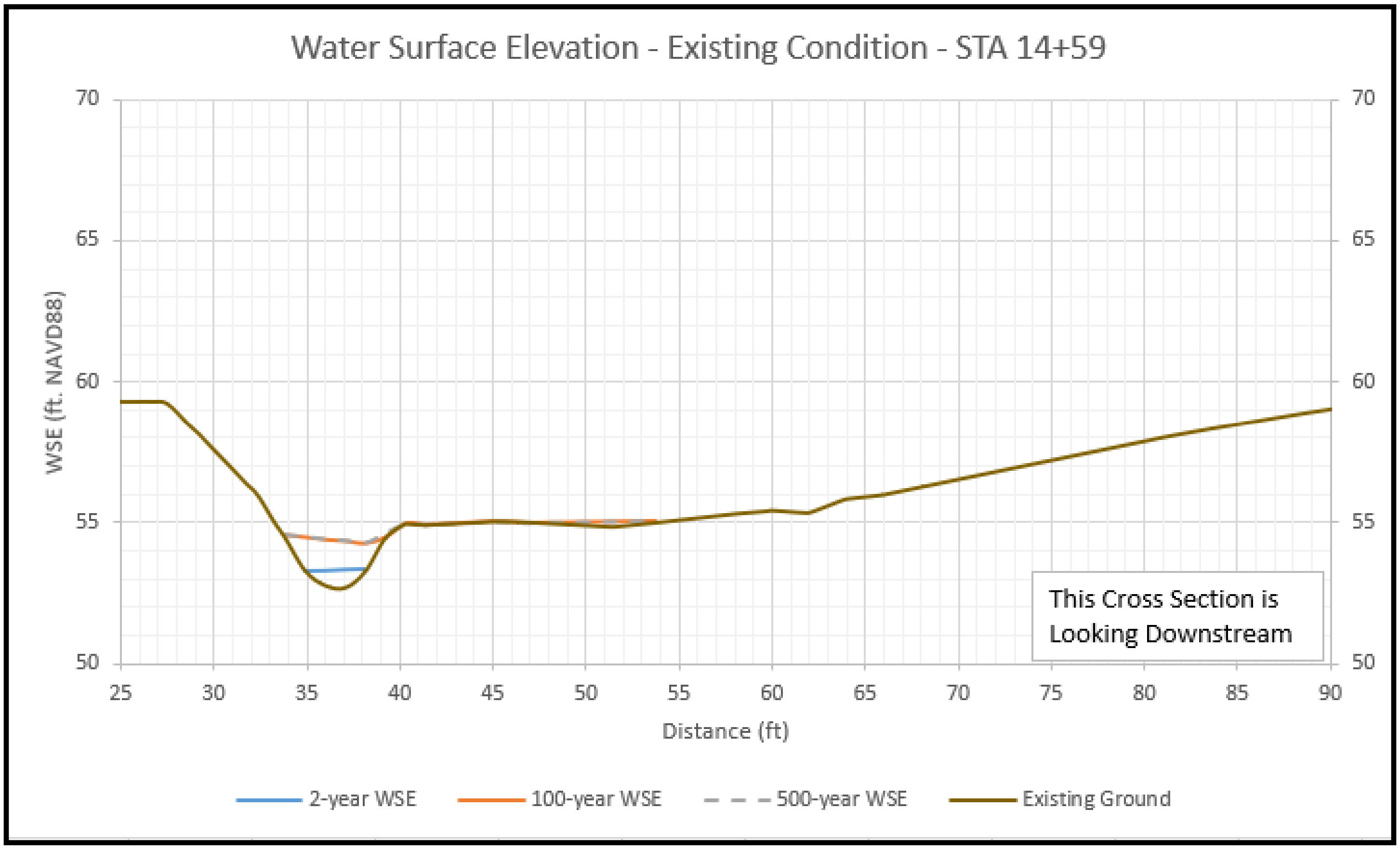
Proposed Condition Cross Section — Station 12+19



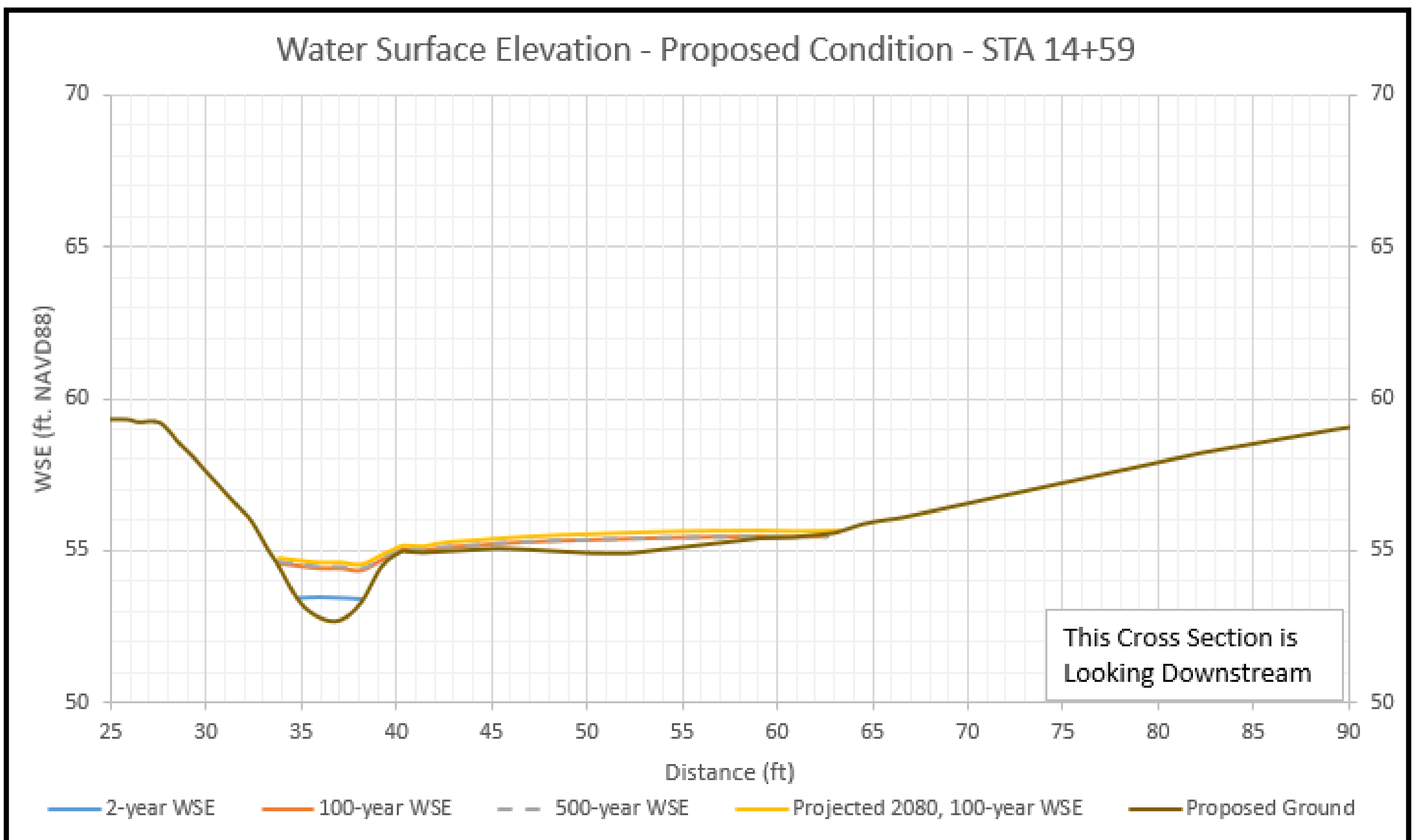
Proposed Condition Crossing—MHO 18ft



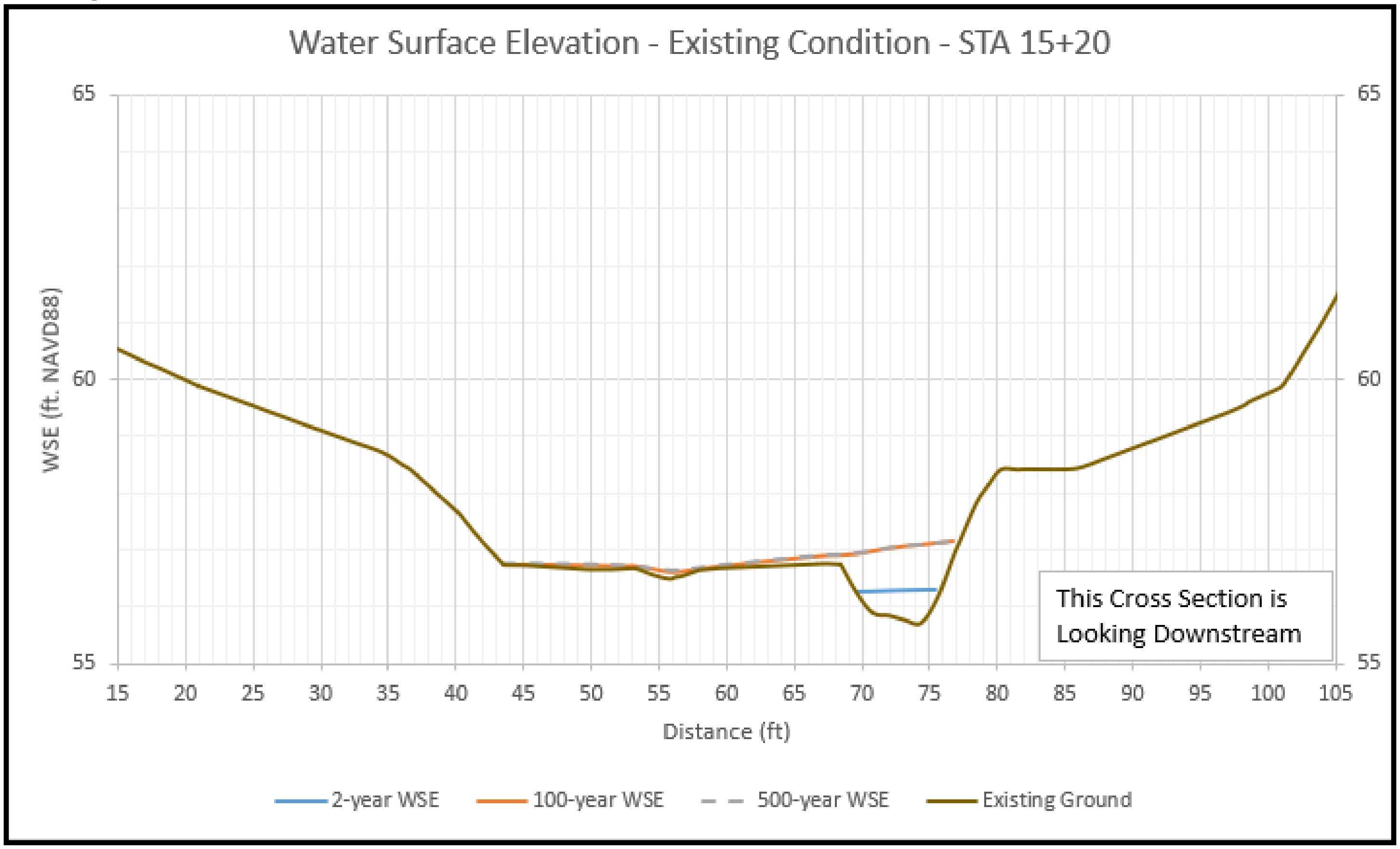
Existing Condition Cross Section — Station 14+59



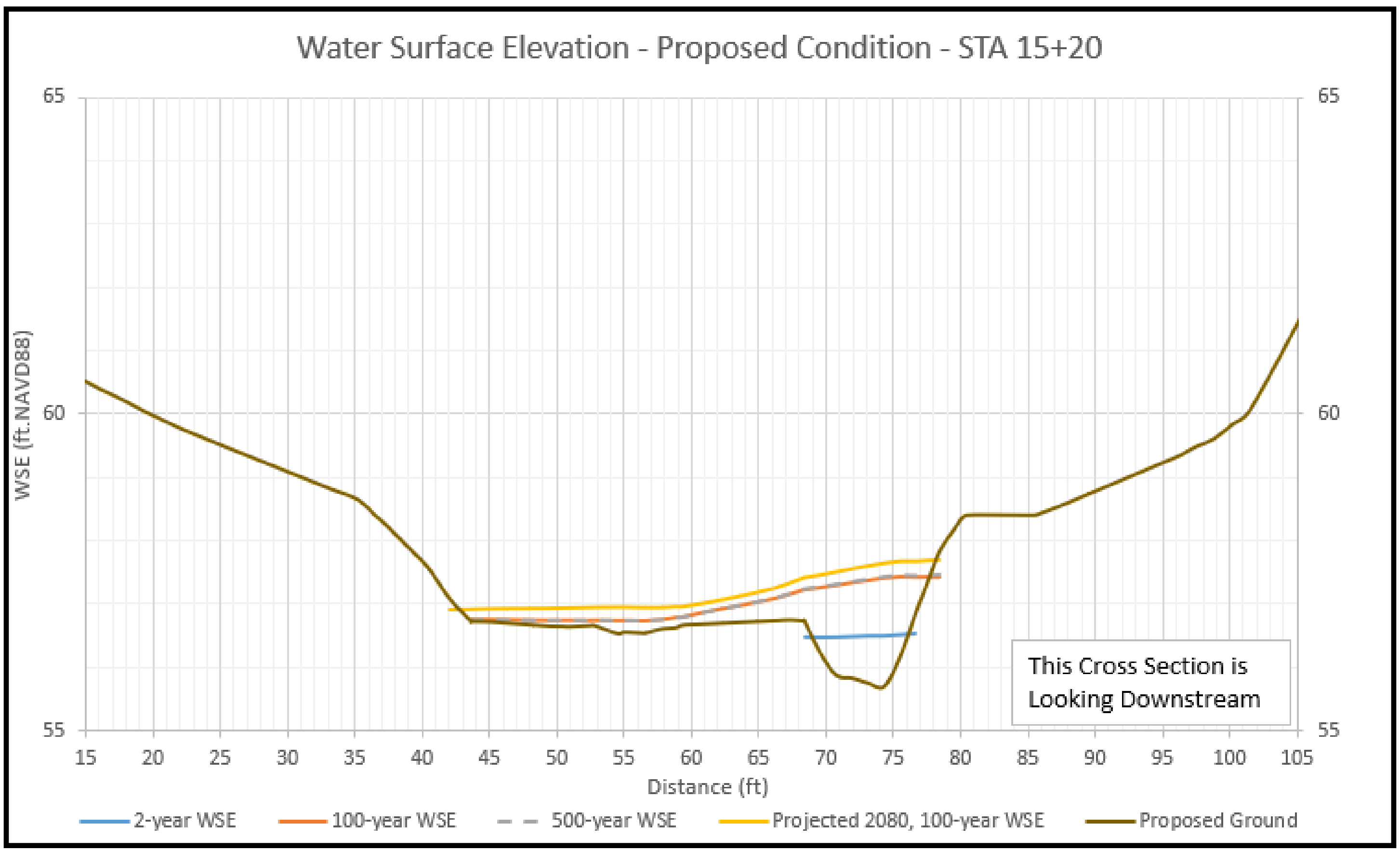
Proposed Condition Cross Section — Station 14+59



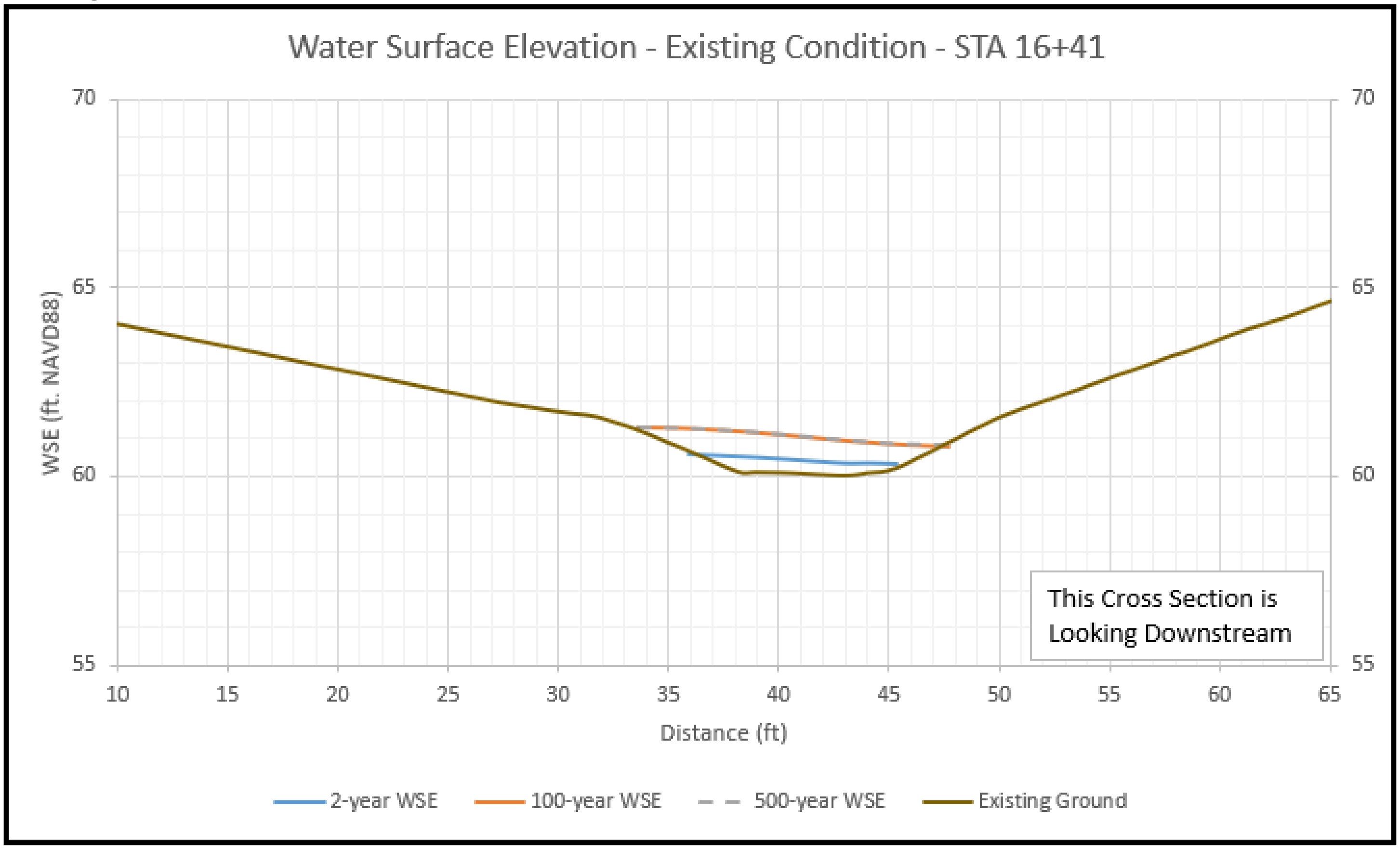
Existing Condition Cross Section — Station 15+20



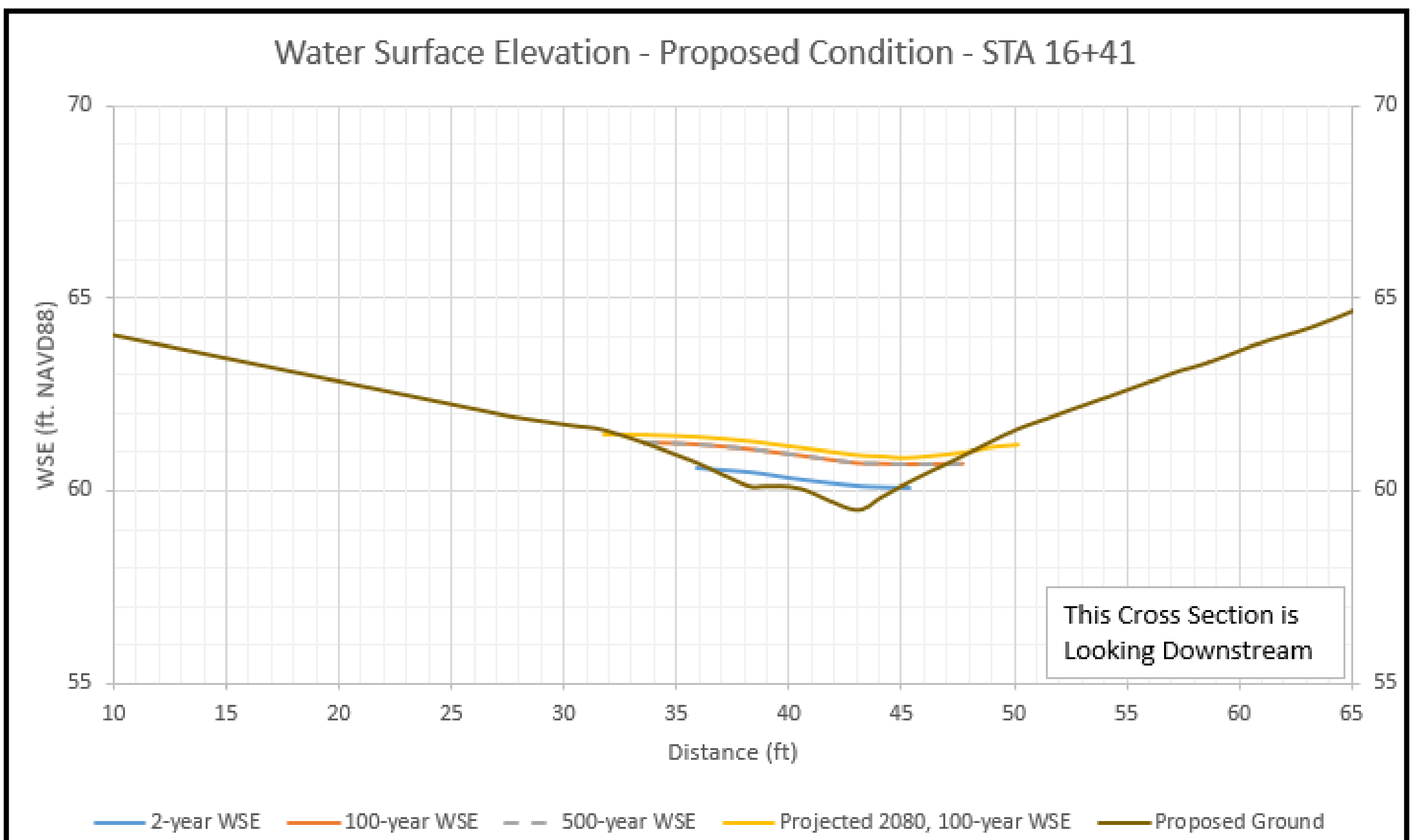
Proposed Condition Cross Section — Station 15+20

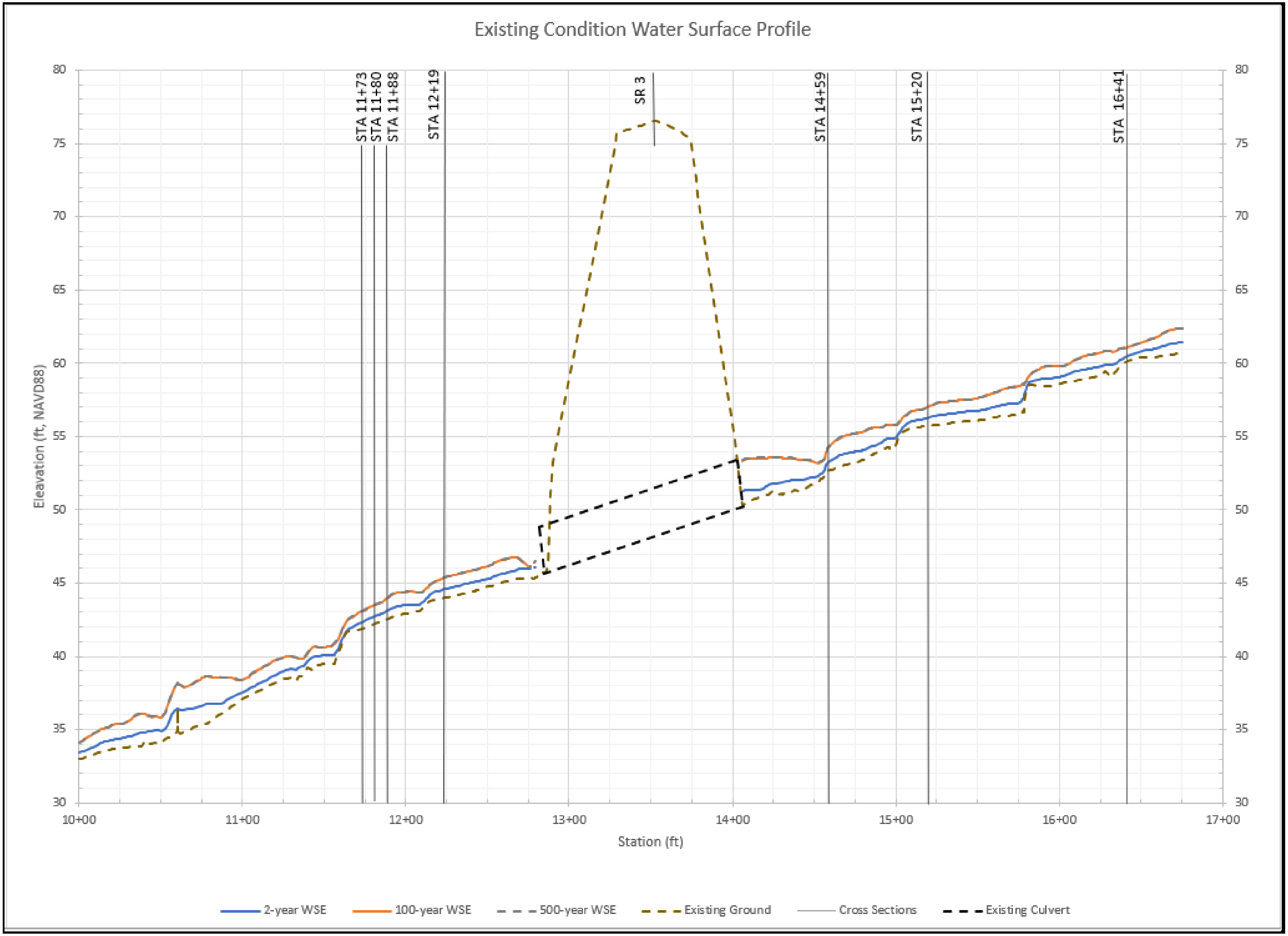


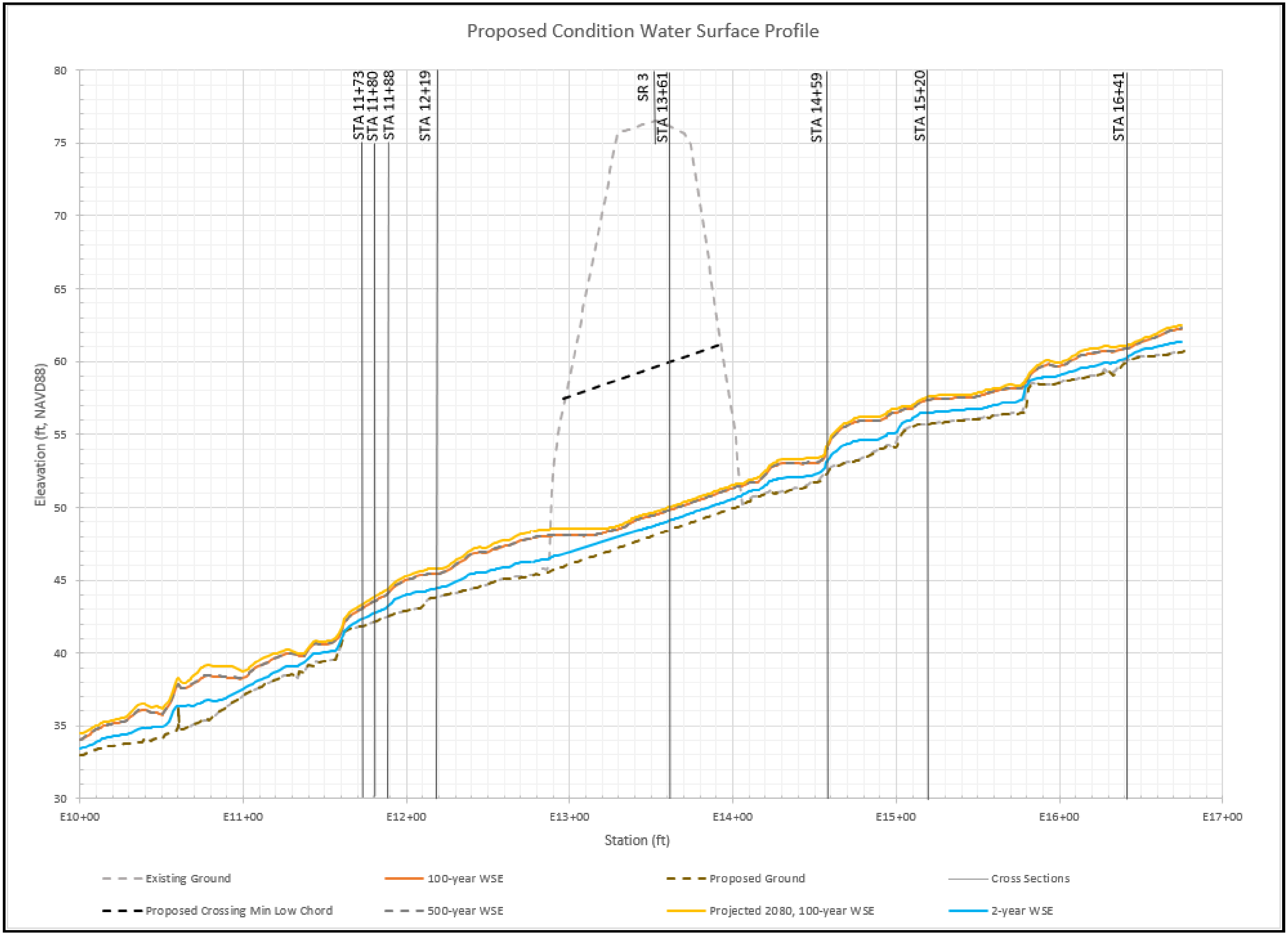
Existing Condition Cross Section — Station 16+41



Proposed Condition Cross Section — Station 16+41

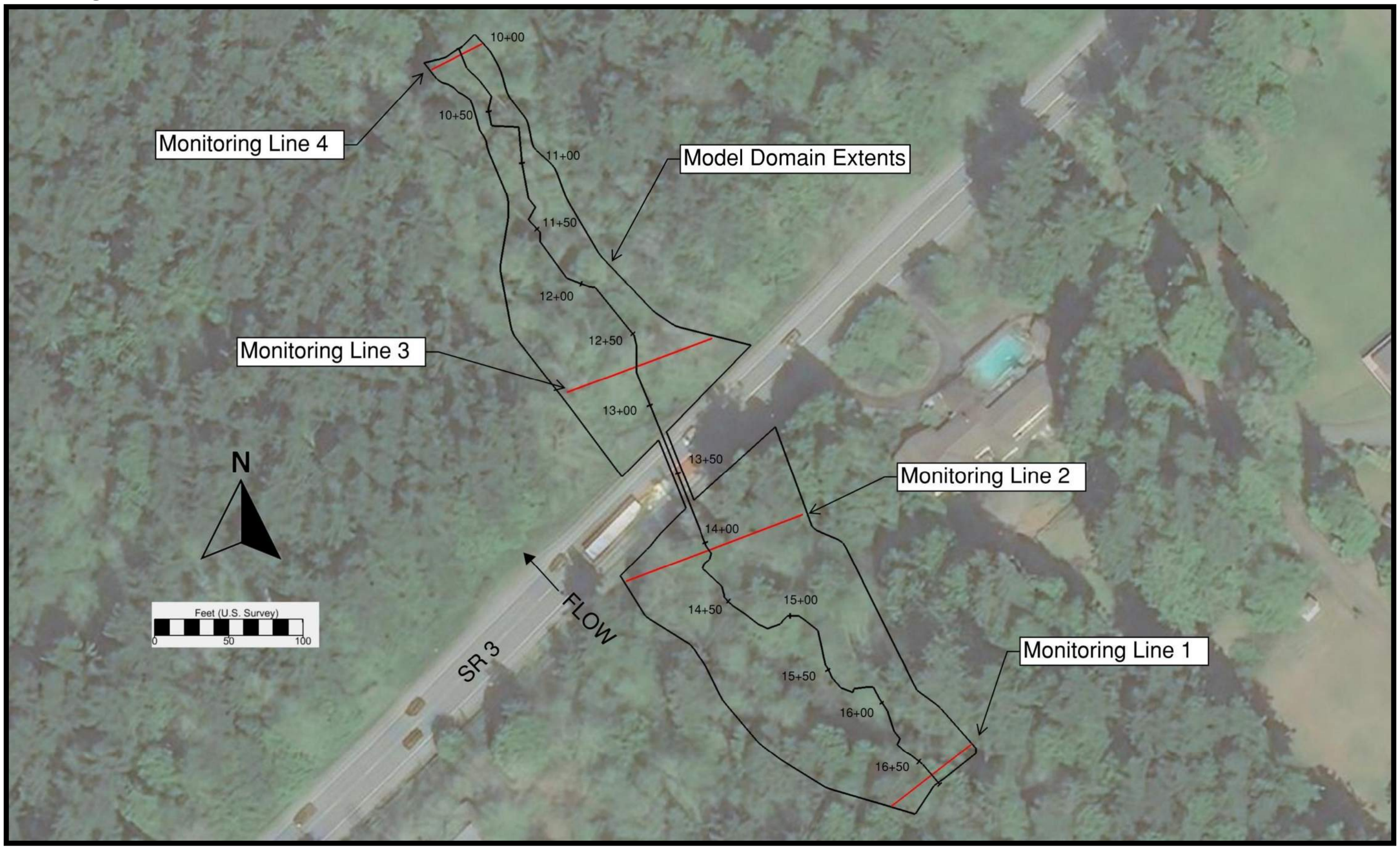



Existing Condition Water Surface Profile
STA 11+73
STA 11+80
STA 11+88
STA 12+19
SR 3
STA 14+59
STA 15+20
STA 16+41
Eleavation (ft, NAVD88)
80
75
70
65
60
55
50
45
40
35
30
10+00
11+00
12+00
13+00
14+00
15+00
16+00
17+00
Station (ft)
2-year WSE
100-year WSE
500-year WSE
Existing Ground
Cross Sections
Existing Culvert

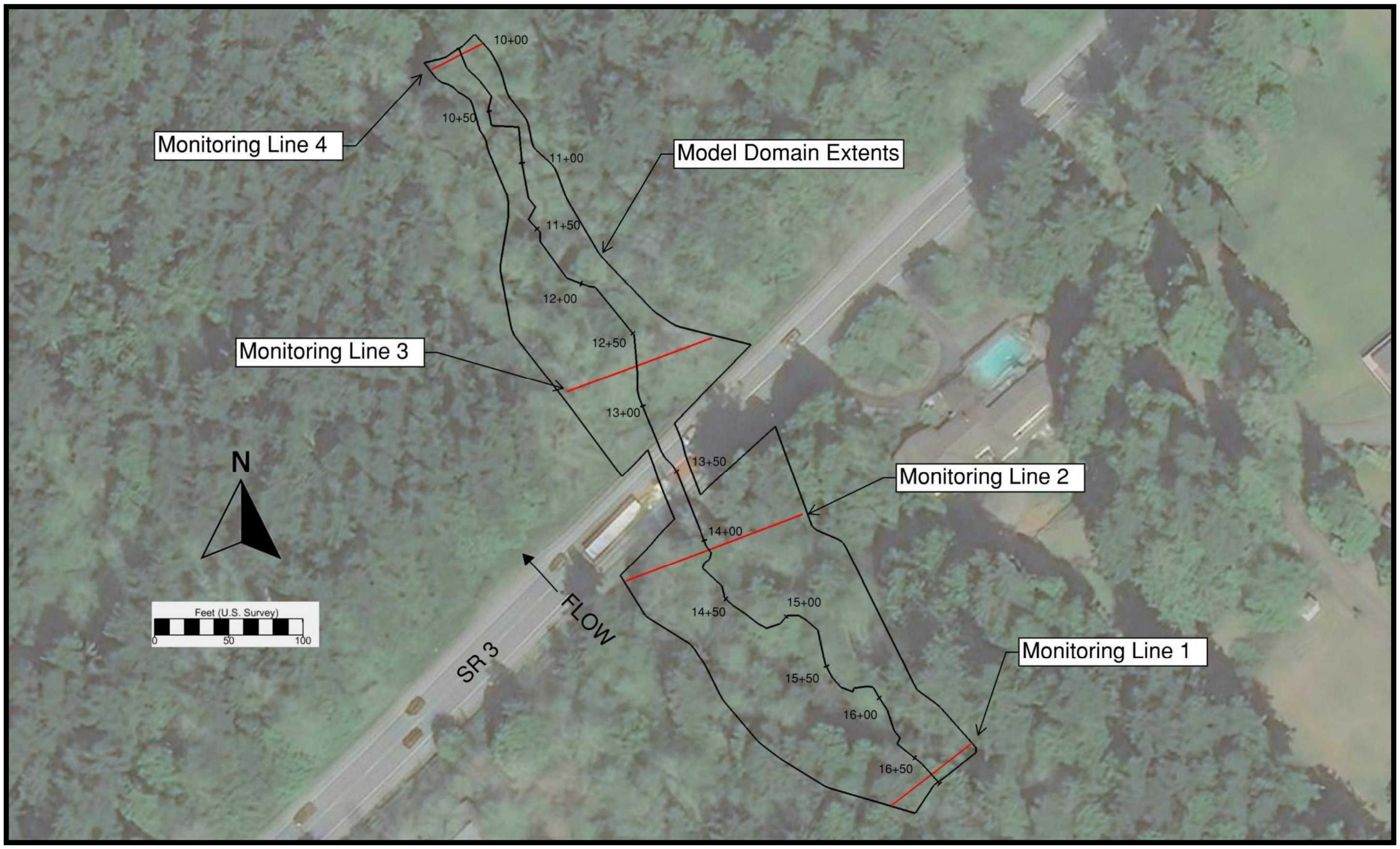

Proposed Condition Water Surface Profile
Eleavation (ft, NAVD88)
80
75
70
65
60
55
50
45
40
35
30
STA 11+73
STA 11+80
STA 11+88
STA 12+19
SR 3
STA 13+61
STA 14+59
STA 15+20
STA 16+41
E10+00
E11+00
E12+00
E13+00
E14+00
E15+00
E16+00
E17+00
Station (ft)
Existing Ground
100-year WSE
Proposed Ground
Cross Sections
Proposed Crossing Min Low Chord
500-year WSE
Projected 2080, 100-year WSE
2-year WSE

Appendix I: SRH-2D Model Stability and Continuity

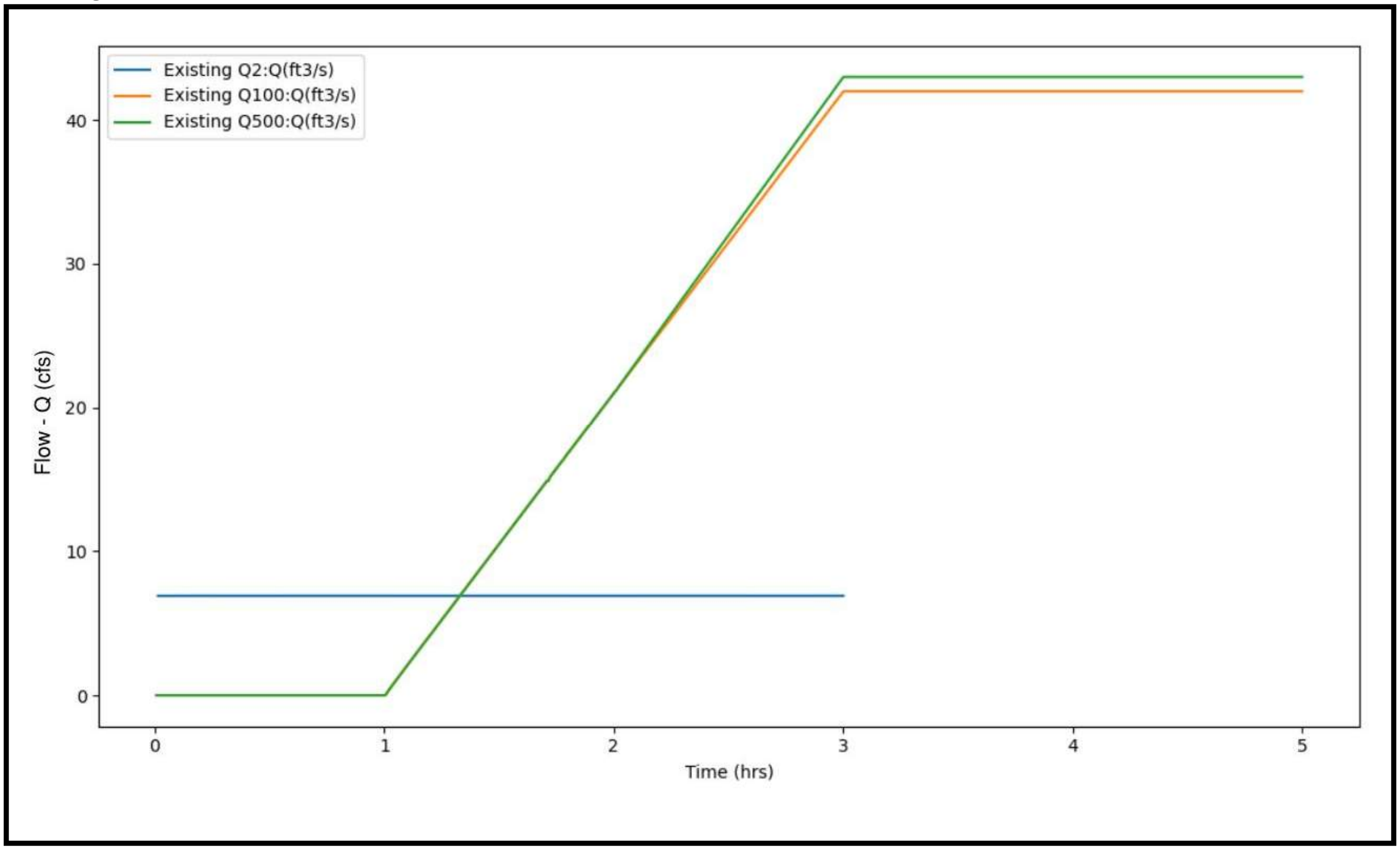
Existing Condition — Monitor Line Locations



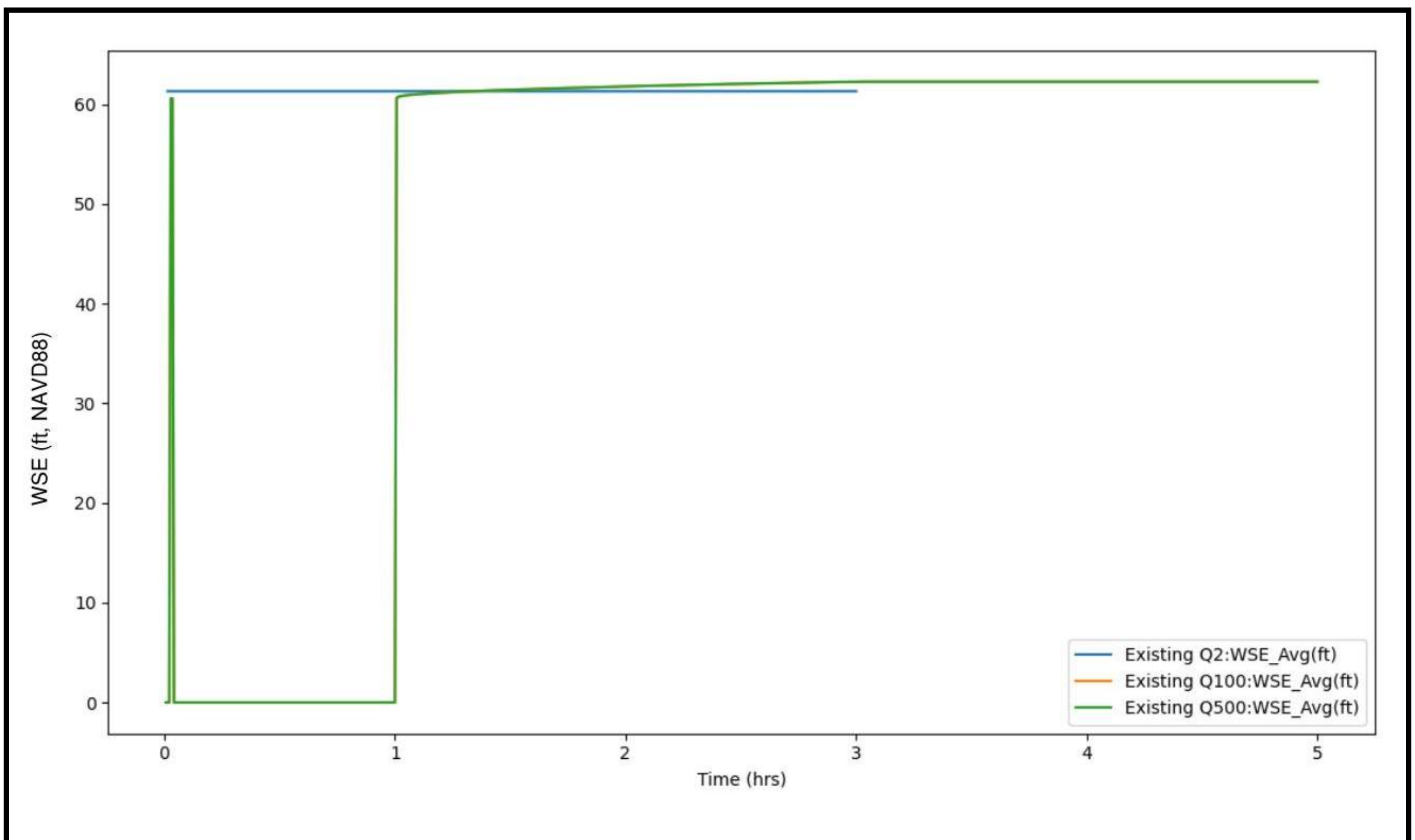
Proposed Condition —Monitor Line Locations



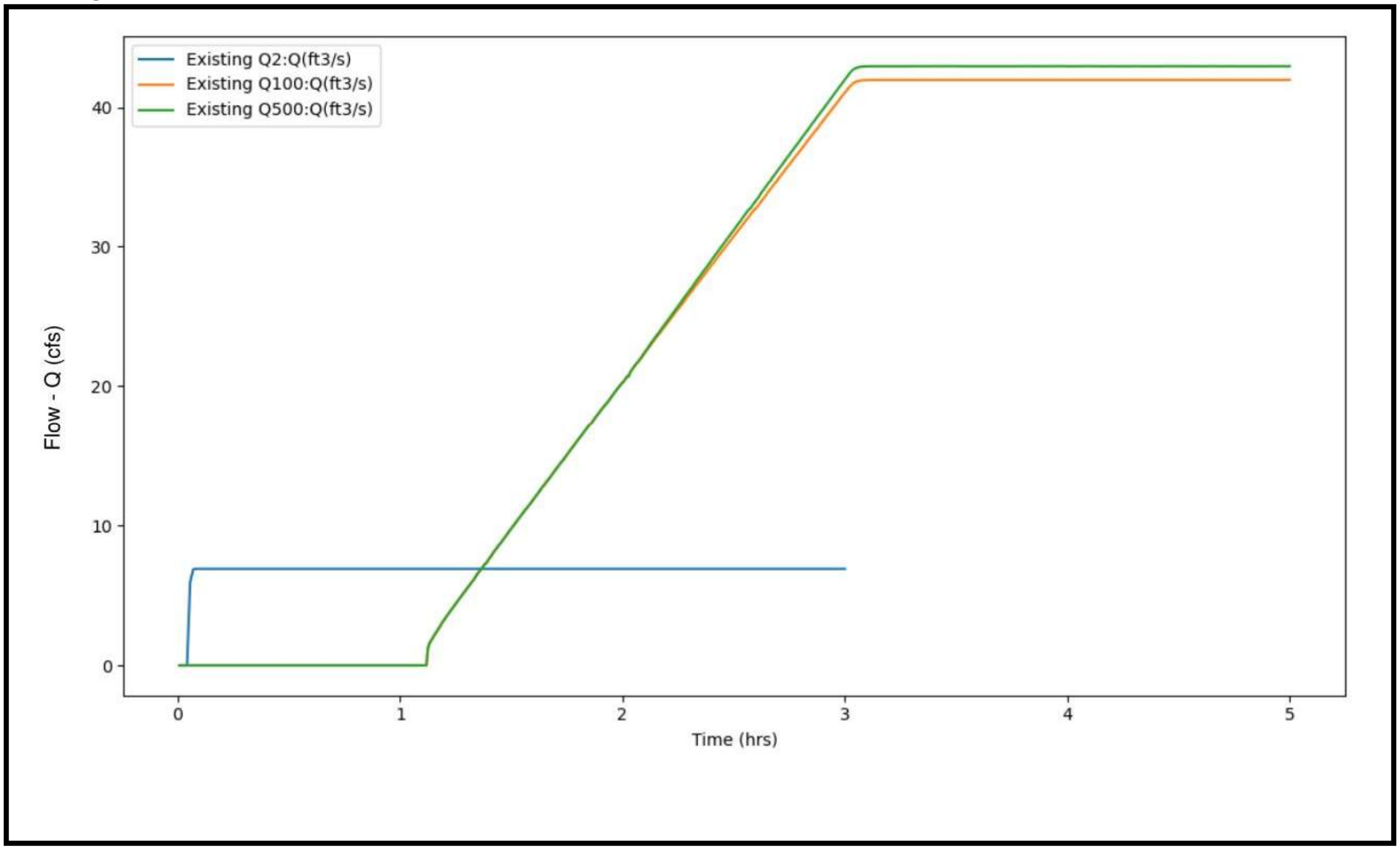
Existing Condition — Monitor Line 1 Flow vs. Time Plot



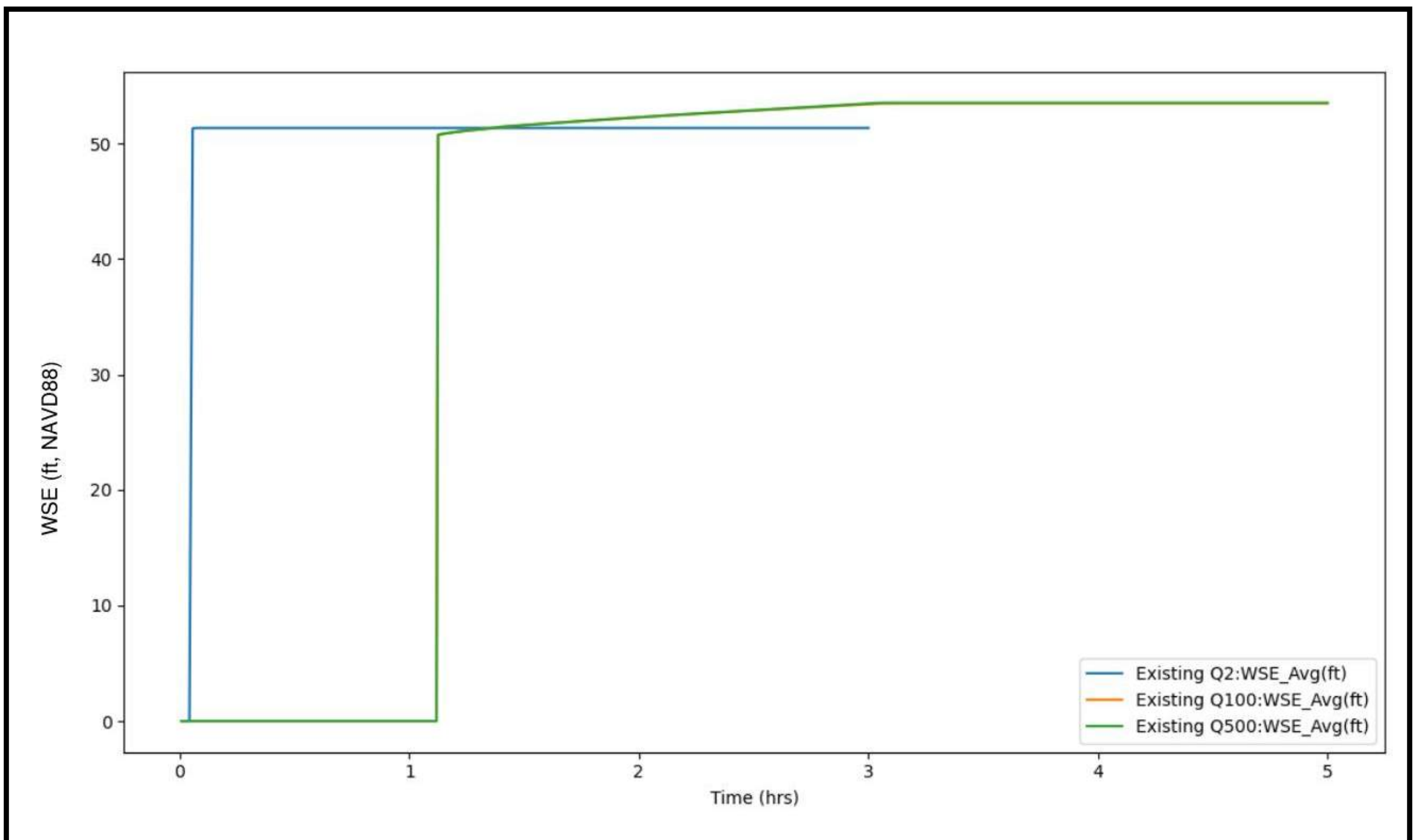
Existing Condition —Monitor Line 1 WSE vs. Time Plot



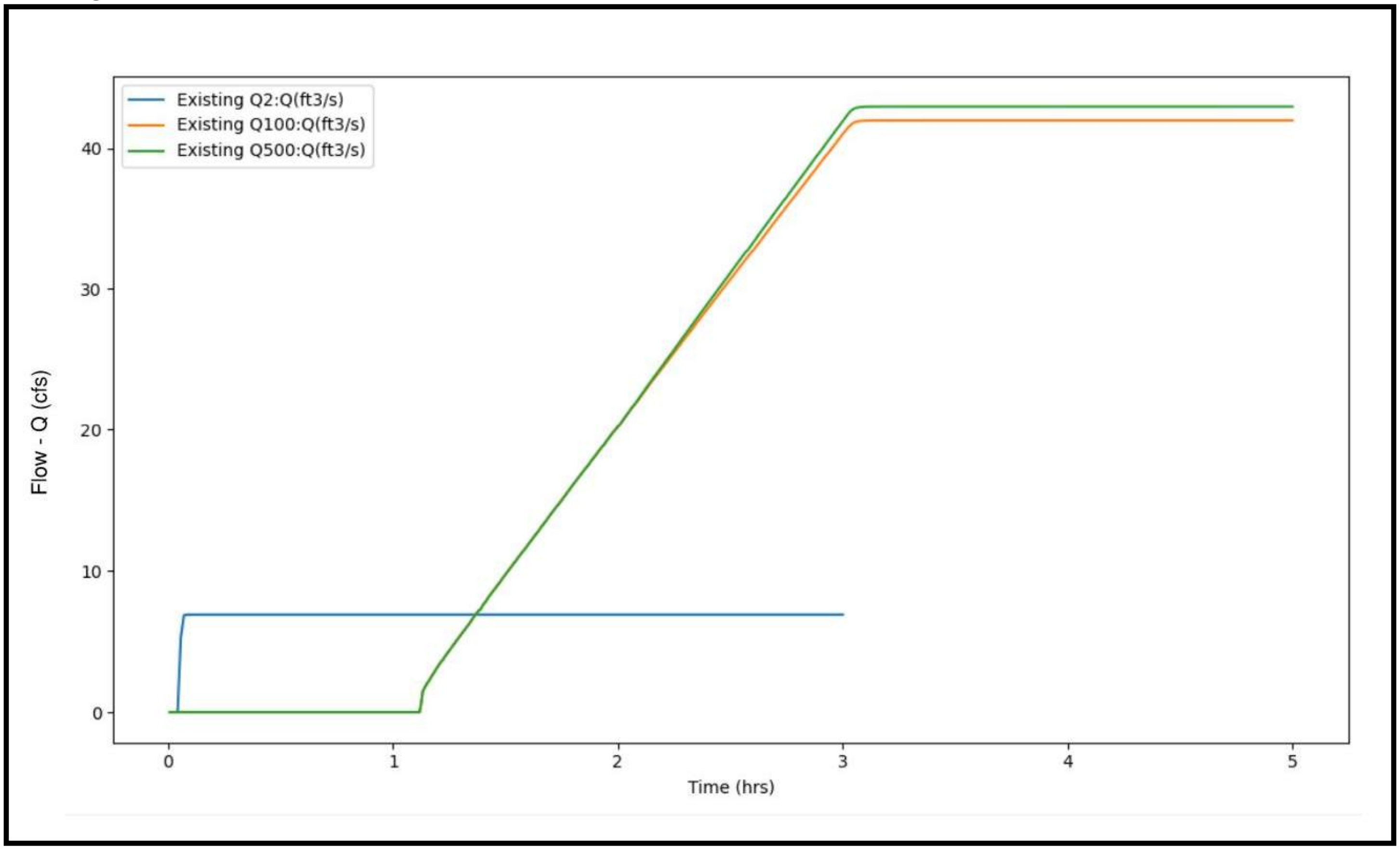
Existing Condition — Monitor Line 2 Flow vs. Time Plot



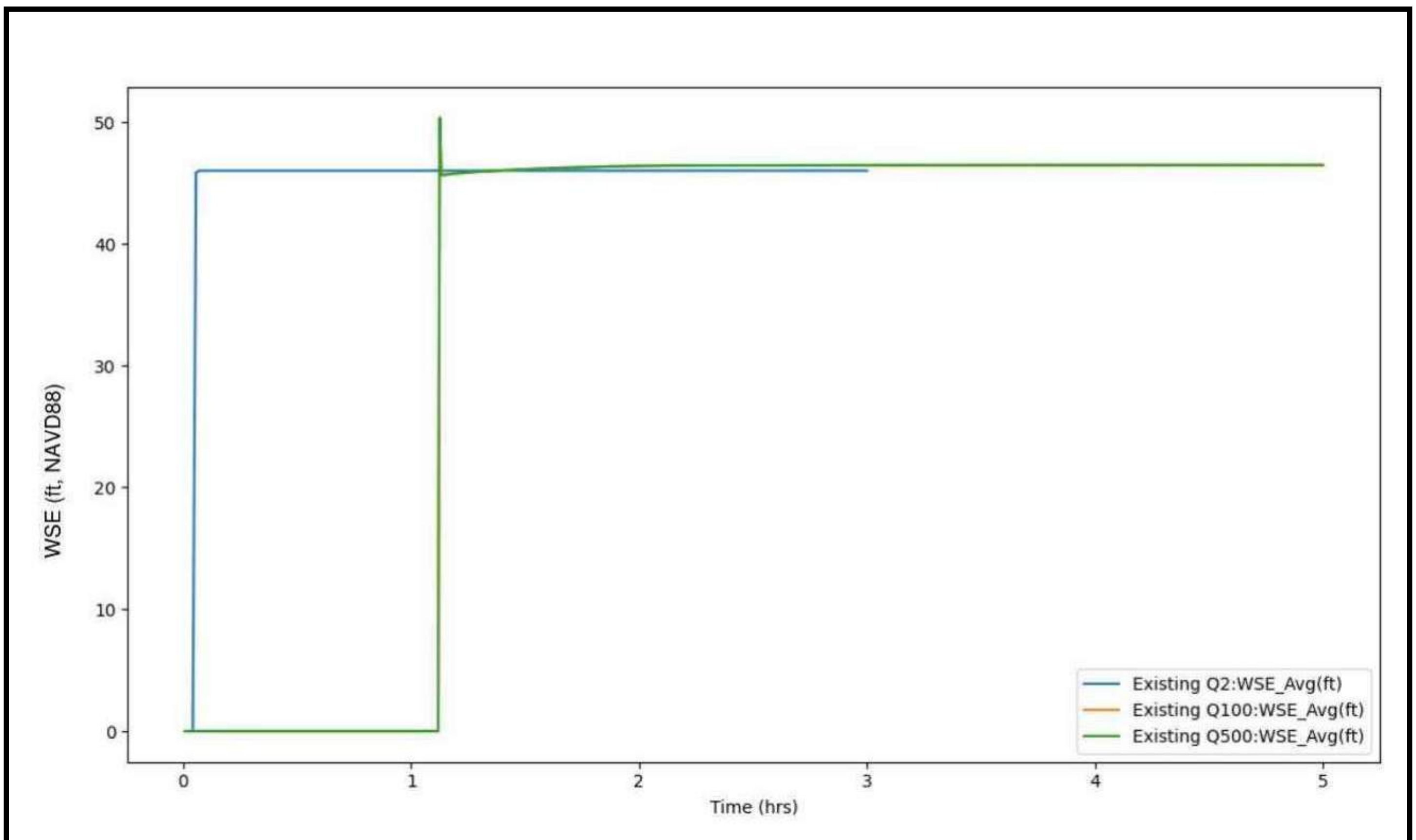
Existing Condition —Monitor Line 2 WSE vs. Time Plot



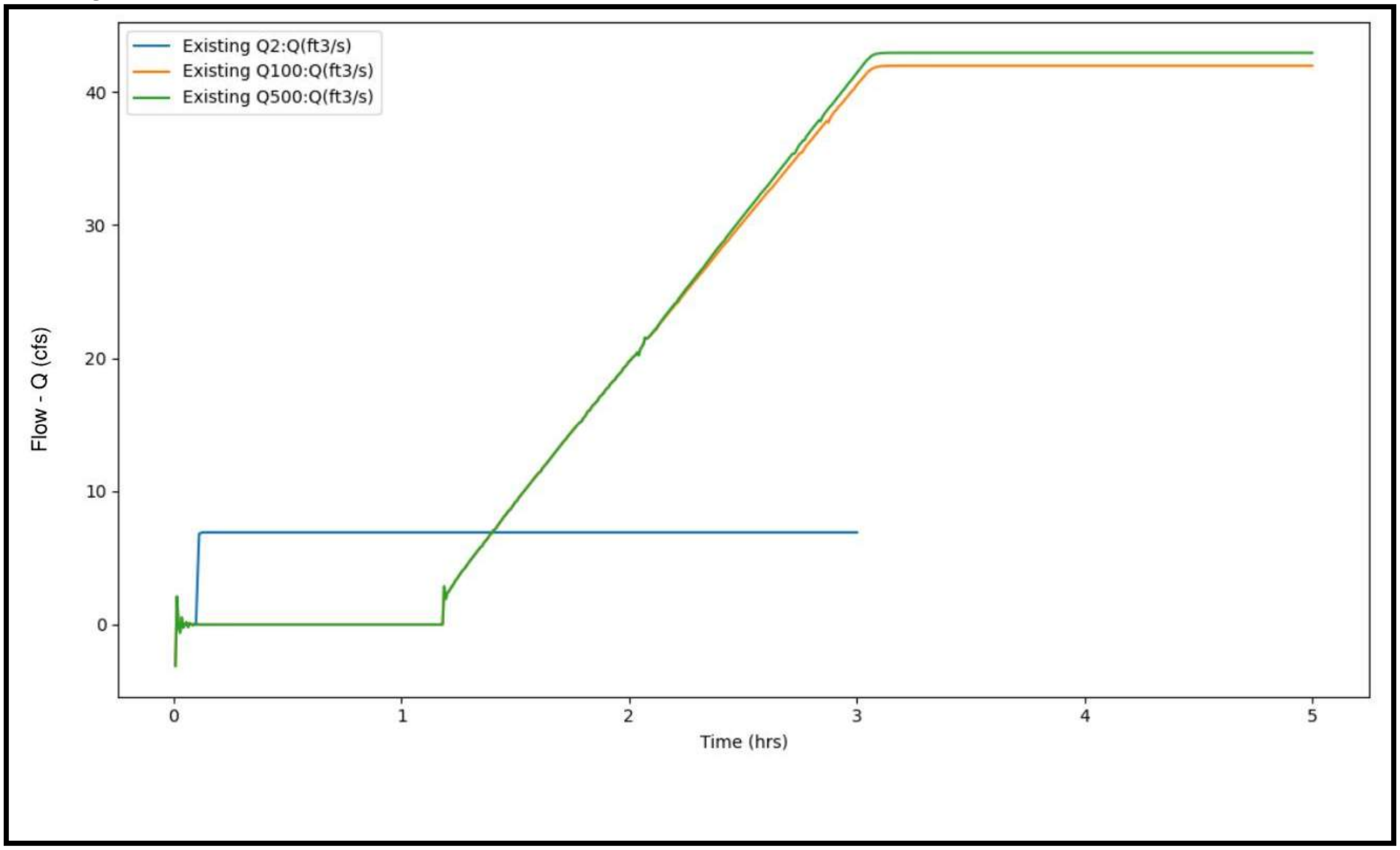
Existing Condition — Monitor Line 3 Flow vs. Time Plot



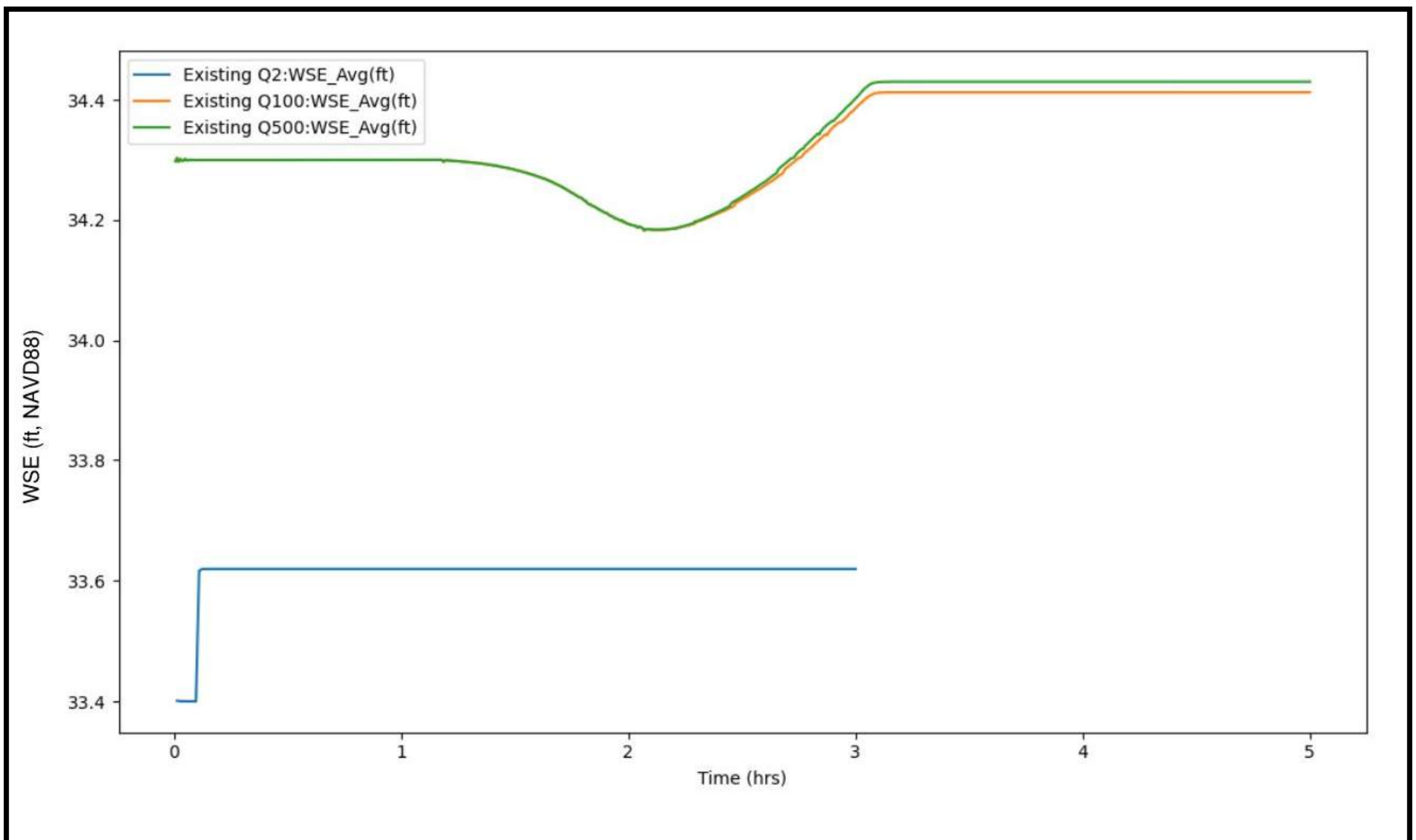
Existing Condition —Monitor Line 3 WSE vs. Time Plot



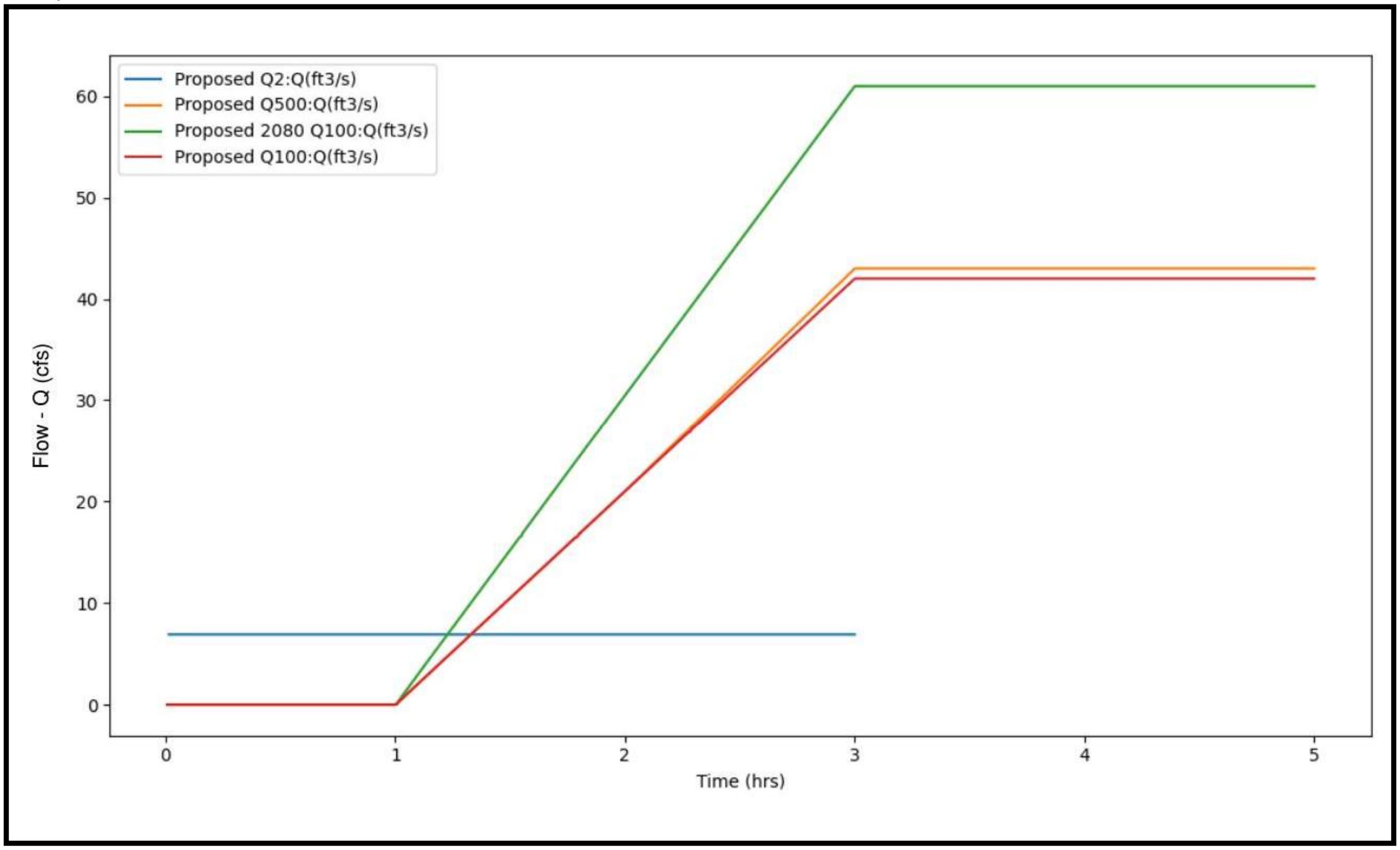
Existing Condition — Monitor Line 4 Flow vs. Time Plot



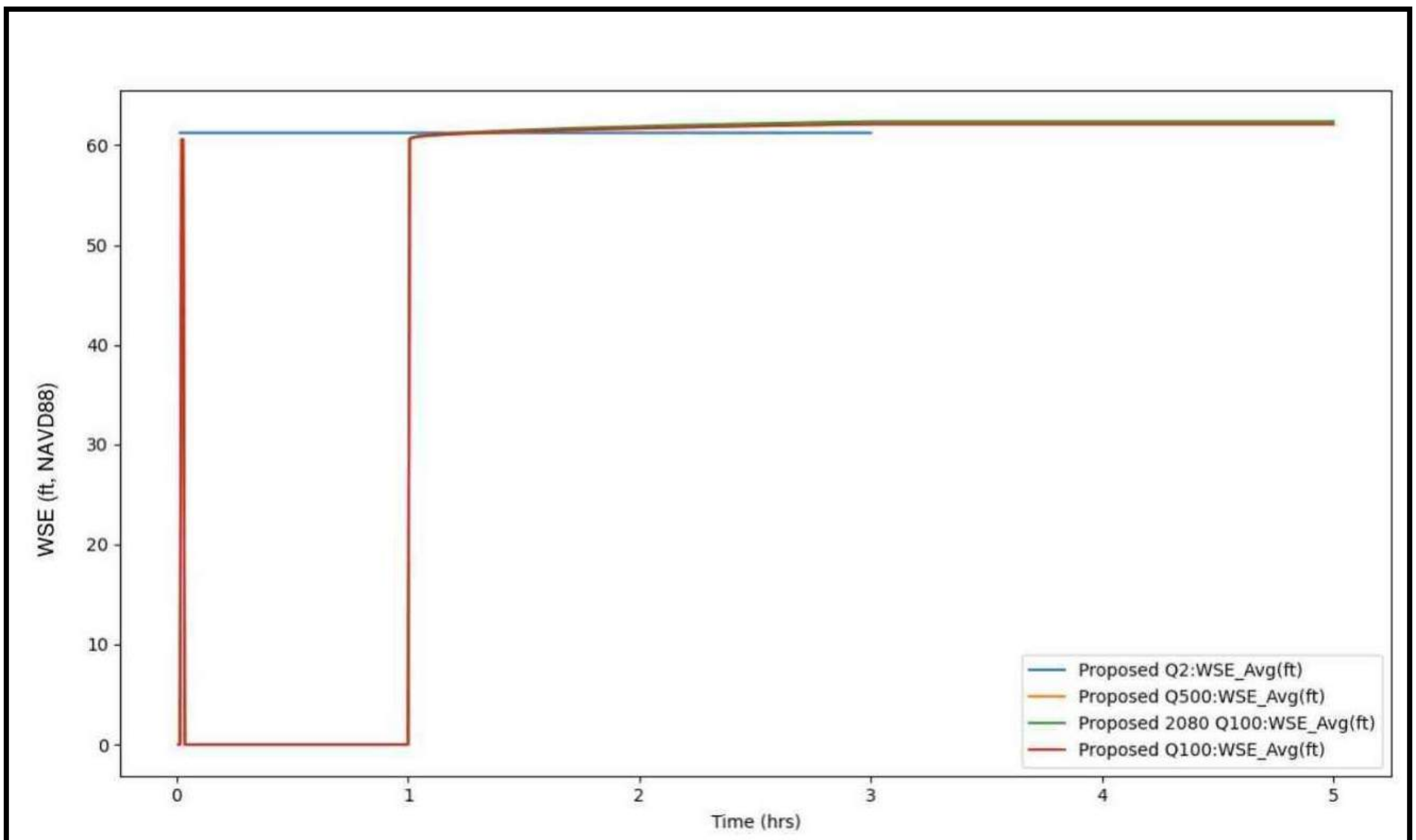
Existing Condition —Monitor Line 4 WSE vs. Time Plot



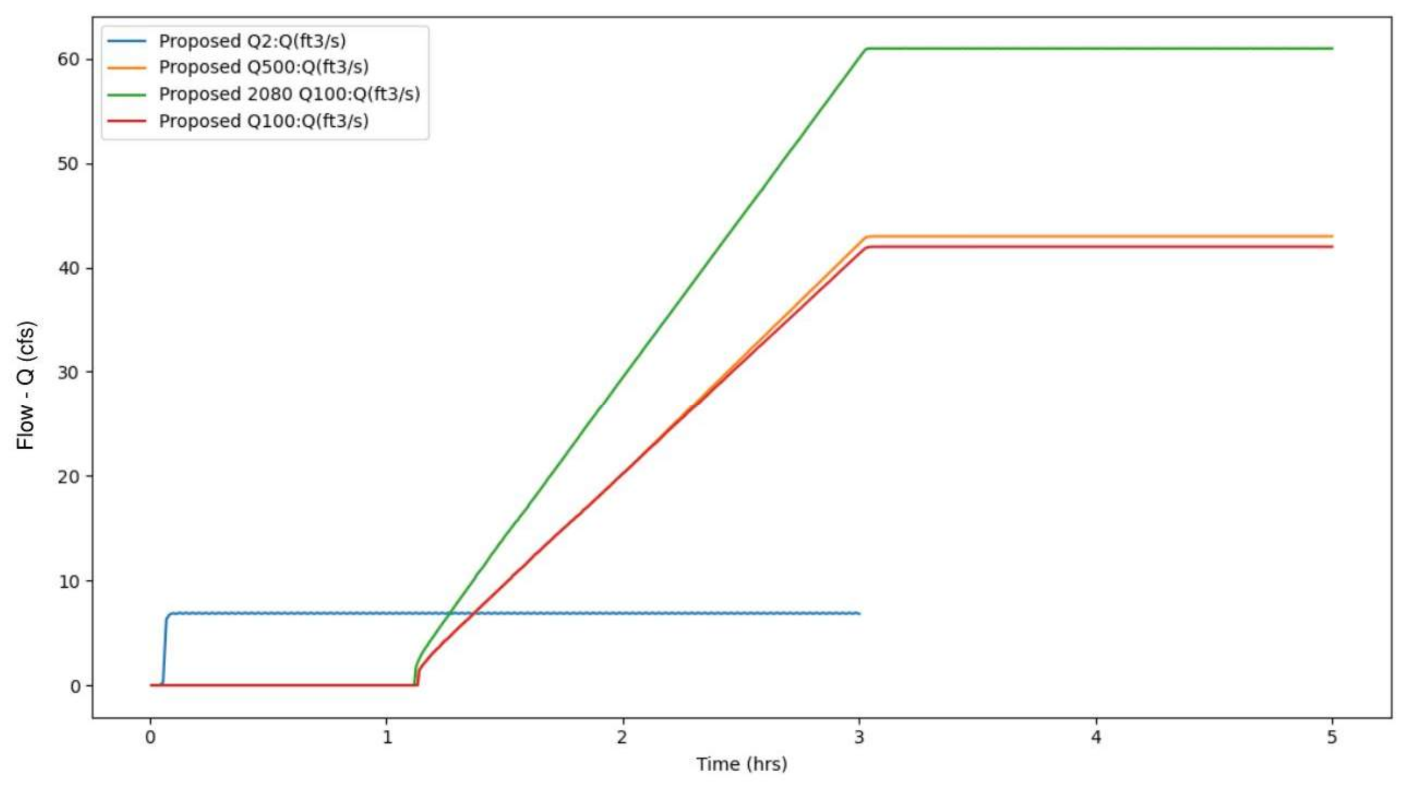
Proposed Condition — Monitor Line 1 Flow vs. Time Plot



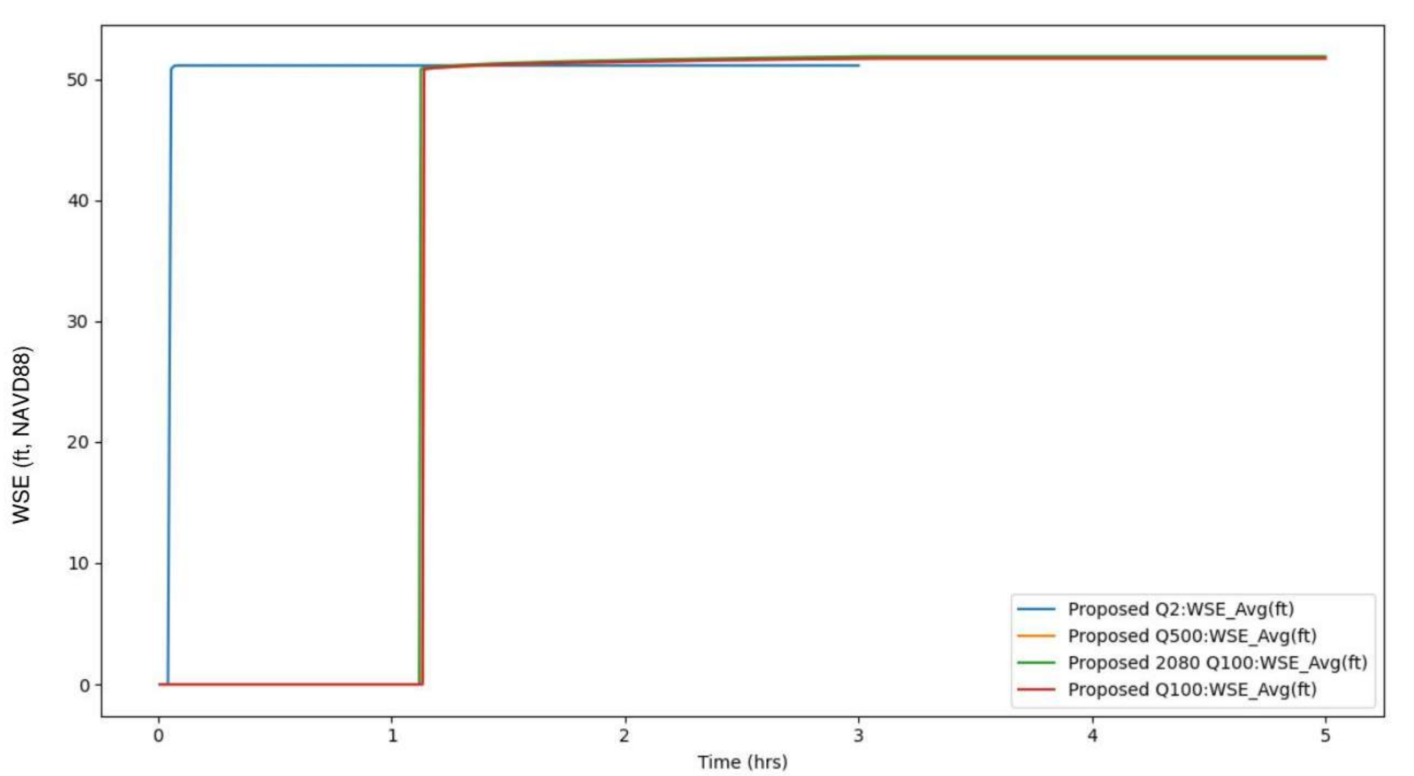
Proposed Condition —Monitor Line 1 WSE vs. Time Plot



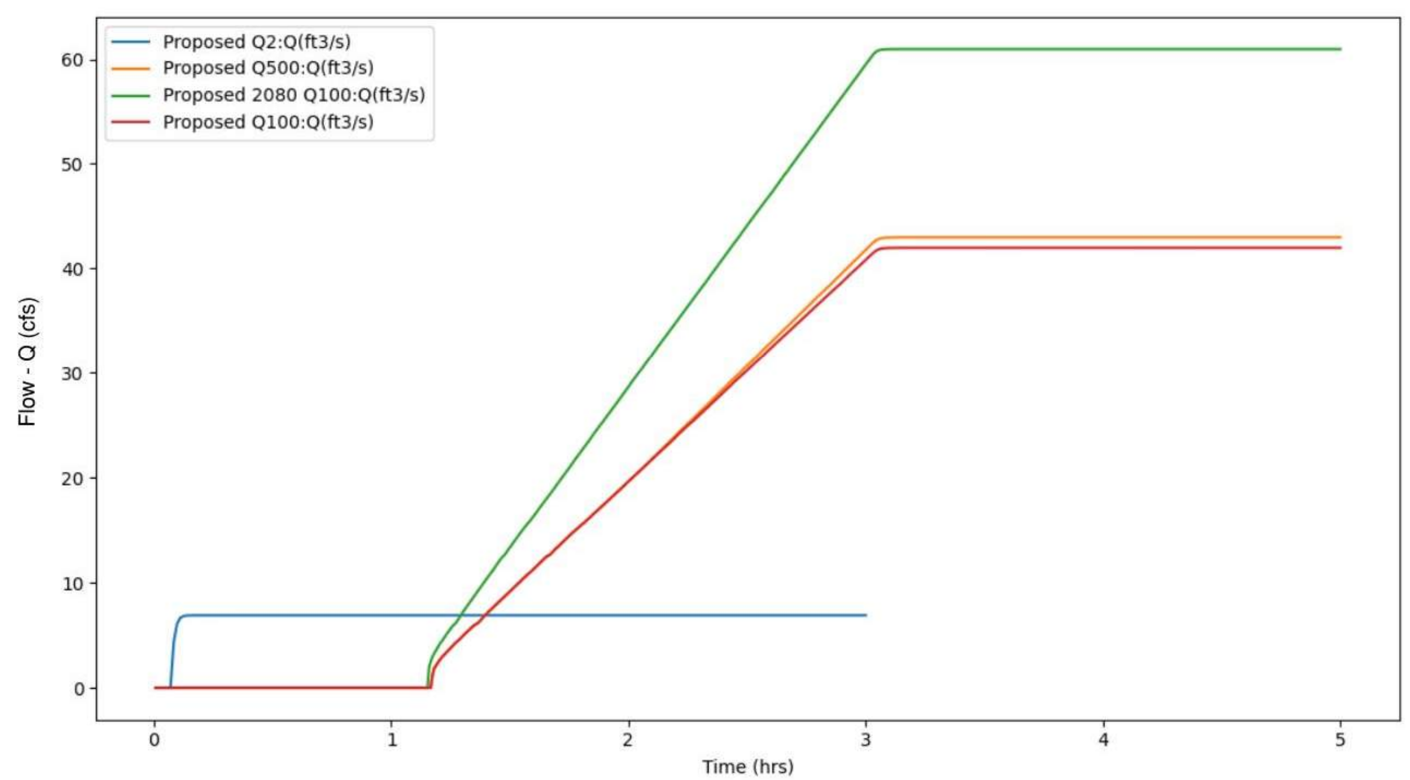
Proposed Condition — Monitor Line 2 Flow vs. Time Plot



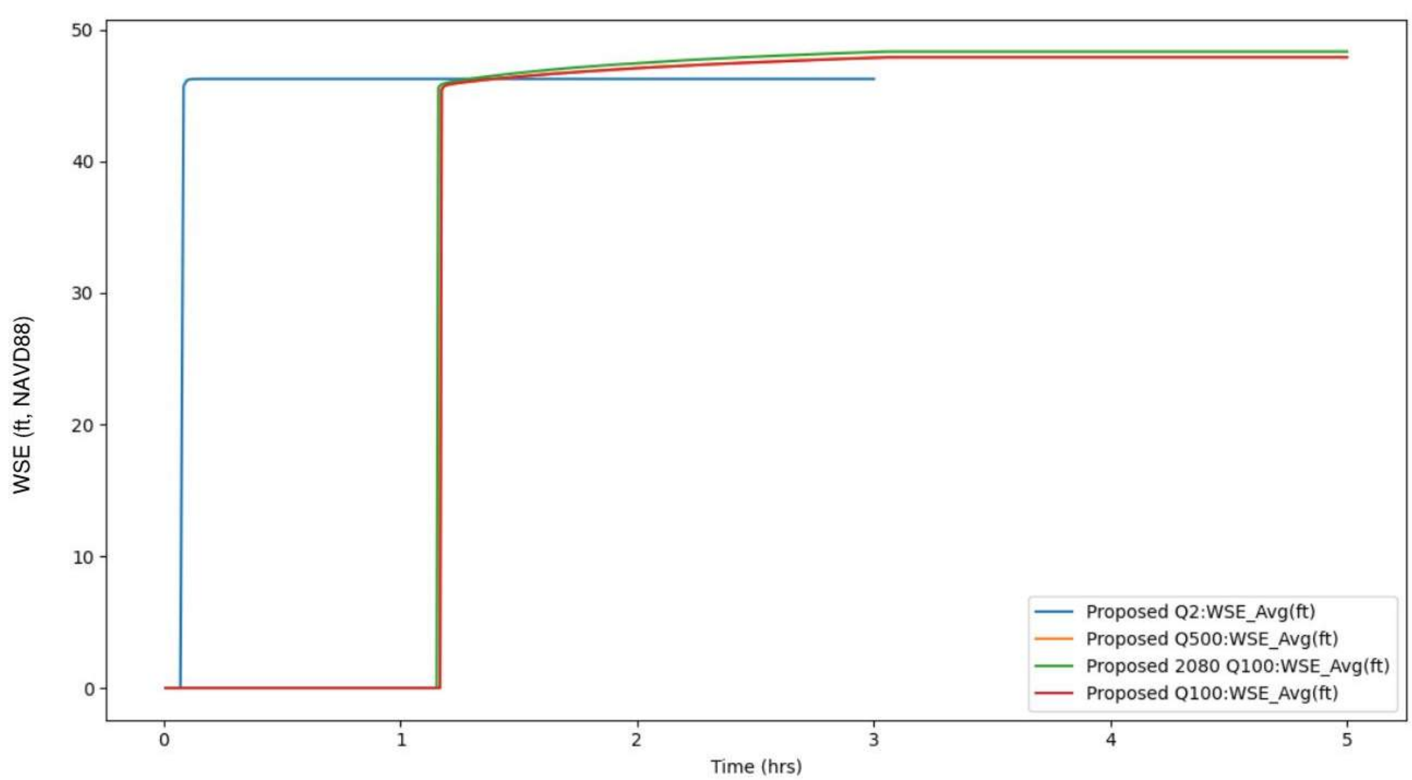
Proposed Condition —Monitor Line 2 WSE vs. Time Plot



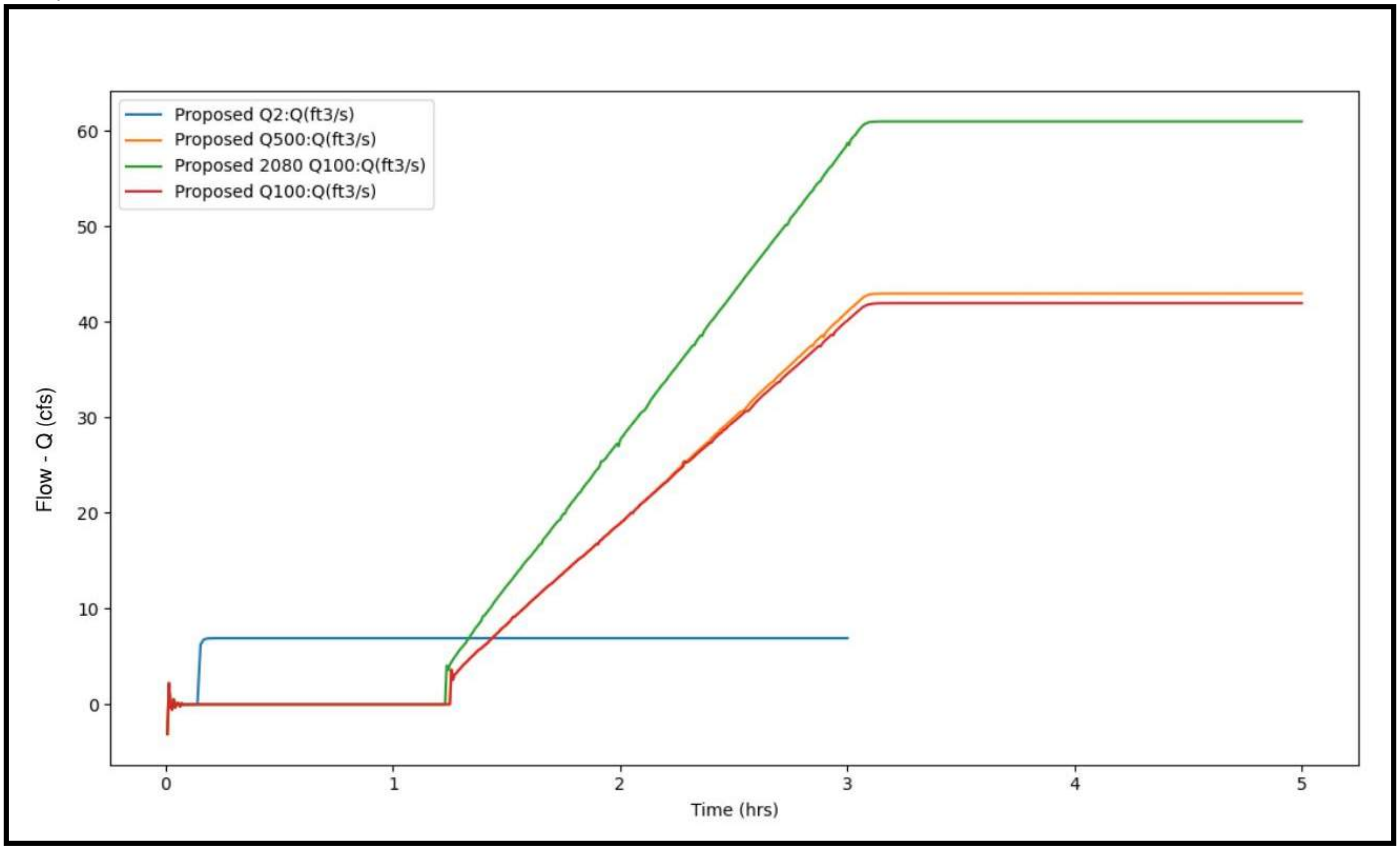
Proposed Condition — Monitor Line 3 Flow vs. Time Plot



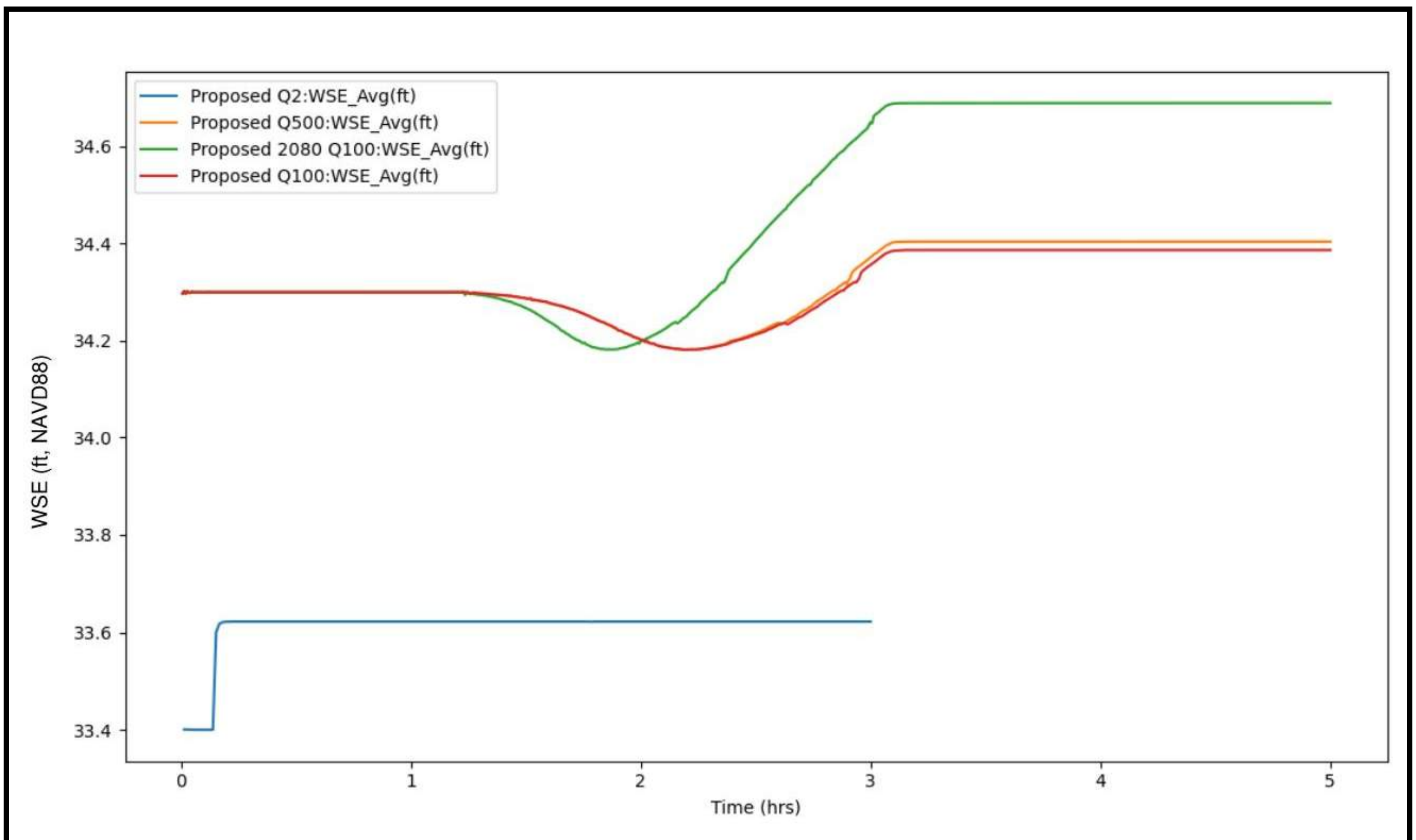
Proposed Condition —Monitor Line 3 WSE vs. Time Plot



Proposed Condition — Monitor Line 4 Flow vs. Time Plot



Proposed Condition —Monitor Line 4 WSE vs. Time Plot



Appendix J: Reach Assessment

There is no reach assessment for Spring Creek to Hood Canal at SR 3 MP 58.49.

Appendix K: Scour Calculations *(FHD ONLY)*

Scour calculations will be provided at the FHD for Spring Creek to Hood Canal at SR 3 MP 58.49.

Appendix L: Floodplain Analysis *(FHD ONLY)*

Floodplain analysis will be provided at the FHD for Spring Creek to Hood Canal at SR 3 MP 58.49.

Appendix M: Scour Countermeasure Calculations *(FHD Only)*

Scour countermeasure calculations will be provided at the FHD for Spring Creek to Hood Canal at SR 3 MP 58.49.

Appendix N: Hydrology

MGS FLOOD
PROJECT REPORT

Program Version: MGSFlood 4.57
Program License Number: 200710001
Project Simulation Performed on: 04/22/2022 3:57 PM
Report Generation Date: 04/22/2022 4:09 PM

Input File Name: 990395_3ft.fld
Project Name: 990395-Hydrology
Analysis Title: Spring Creek to Hood Canal - 3ft
Comments:
Hydrology developed using 3ft slope data
Created by: Tonmoy Sarker, PE
QC: Tyler Jantzen, PE

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Time Series Selected
Climatic Region Number: 2

Full Period of Record Available used for Routing
Precipitation Station : 95003605 Puget West 36 in_5min 10/01/1939-10/01/2097
Evaporation Station : 951036 Puget West 36 in MAP
Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name : Ecology Default

********** Default HSPF Parameters Used (Not Modified by User) ***************

********************** WATERSHED DEFINITION **********************

Predevelopment/Post Development Tributary Area Summary

	Predeveloped	Post Developed
Total Subbasin Area (acres)	408.464	408.463
Area of Links that Include Precip/Evap (acres)	0.000	0.000
Total (acres)	408.464	408.463

----------------------SCENARIO: 990395-SA1
Number of Subbasins: 1

---------- Subbasin : 990395 ----------

	-------Area (Acres) --------
A/B, Forest, Flat	9.260
A/B, Forest, Mod	31.419
A/B, Forest, Steep	185.371
A/B, Pasture, Flat	0.189
A/B, Pasture, Mod	0.251
A/B, Pasture, Steep	0.005
A/B, Lawn, Flat	3.188
A/B, Lawn, Mod	5.333
A/B, Lawn, Steep	5.703
C, Forest, Flat	0.200
C, Forest, Mod	0.606
C, Forest, Steep	1.019
C, Lawn, Flat	0.189
C, Lawn, Mod	0.394
C, Lawn, Steep	0.515
SAT, Forest, Flat	27.301
SAT, Forest, Mod	64.749
SAT, Forest, Steep	53.141

SAT, Lawn, Flat 1.545
SAT, Lawn, Mod 5.563
SAT, Lawn, Steep 6.639
ROADS/FLAT 1.608
ROADS/MOD 2.410
ROADS/STEEP 1.866

Subbasin Total 408.464

---------------------SCENARIO: 990395-SA2
Number of Subbasins: 6

---------- Subbasin : 990395D ----------
-------Area (Acres) --------
A/B, Forest, Flat 0.712
A/B, Forest, Mod 3.794
A/B, Forest, Steep 62.827
A/B, Lawn, Flat 0.004
A/B, Lawn, Mod 0.100
A/B, Lawn, Steep 0.360
SAT, Forest, Flat 2.798
SAT, Forest, Mod 7.114
SAT, Forest, Steep 13.529

Subbasin Total 91.237

---------- Subbasin : 990395E ----------
-------Area (Acres) --------
A/B, Forest, Flat 0.314
A/B, Forest, Mod 1.681
A/B, Forest, Steep 20.640
SAT, Forest, Flat 1.374
SAT, Forest, Mod 4.042
SAT, Forest, Steep 8.341

Subbasin Total 36.393

---------- Subbasin : 990395F ----------
-------Area (Acres) --------
A/B, Forest, Flat 5.552
A/B, Forest, Mod 14.664
A/B, Forest, Steep 70.566
A/B, Lawn, Flat 0.001
A/B, Lawn, Mod 0.012
A/B, Lawn, Steep 0.212
SAT, Forest, Flat 21.243
SAT, Forest, Mod 44.779
SAT, Forest, Steep 24.112
SAT, Lawn, Flat 0.181
SAT, Lawn, Mod 1.660
SAT, Lawn, Steep 4.414

Subbasin Total 187.394

---------- Subbasin : 990395B ----------
-------Area (Acres) --------
A/B, Forest, Flat 0.492
A/B, Forest, Mod 3.300
A/B, Forest, Steep 16.395
A/B, Lawn, Flat 0.022
A/B, Lawn, Mod 0.153
A/B, Lawn, Steep 0.560
C, Forest, Flat 0.002
C, Forest, Mod 0.031
C, Forest, Steep 0.472
C, Lawn, Flat 0.000

C, Lawn, Mod 0.015
C, Lawn, Steep 0.164
SAT, Forest, Flat 0.039
SAT, Forest, Mod 0.272
SAT, Forest, Steep 1.030
ROADS/FLAT 0.003
ROADS/MOD 0.017
ROADS/STEEP 0.103

Subbasin Total 23.067

---------- Subbasin : 990395A ----------
-------Area (Acres) --------
A/B, Forest, Flat 1.904
A/B, Forest, Mod 5.937
A/B, Forest, Steep 10.601
A/B, Pasture, Flat 0.189
A/B, Pasture, Mod 0.251
A/B, Pasture, Steep 0.005
A/B, Lawn, Flat 2.968
A/B, Lawn, Mod 3.496
A/B, Lawn, Steep 1.676
SAT, Forest, Flat 0.898
SAT, Forest, Mod 3.712
SAT, Forest, Steep 1.971
SAT, Lawn, Flat 1.332
SAT, Lawn, Mod 3.262
SAT, Lawn, Steep 1.148
ROADS/FLAT 1.505
ROADS/MOD 2.005
ROADS/STEEP 0.694

Subbasin Total 43.552

---------- Subbasin : 990395C ----------
-------Area (Acres) --------
A/B, Forest, Flat 0.287
A/B, Forest, Mod 2.043
A/B, Forest, Steep 4.343
A/B, Lawn, Flat 0.194
A/B, Lawn, Mod 1.572
A/B, Lawn, Steep 2.897
C, Forest, Flat 0.198
C, Forest, Mod 0.575
C, Forest, Steep 0.548
C, Lawn, Flat 0.189
C, Lawn, Mod 0.379
C, Lawn, Steep 0.351
SAT, Forest, Flat 0.948
SAT, Forest, Mod 4.829
SAT, Forest, Steep 4.158
SAT, Lawn, Flat 0.032
SAT, Lawn, Mod 0.641
SAT, Lawn, Steep 1.077
ROADS/FLAT 0.101
ROADS/MOD 0.389
ROADS/STEEP 1.070

Subbasin Total 26.820

**************************** LINK DATA ******************************

---------------------SCENARIO: 990395-SA1
Number of Links: 0

************************* **LINK DATA** *******************************

----------------------SCENARIO: 990395-SA2
Number of Links: 7

Link Name: XS-F
Link Type: Open Channel
Downstream Link Name: XS-B

----------Left Overbank
Upper Sideslope (z) : 2.000
Upper Width (ft) : 20.000
Middle Sideslope (z) : 2.000
Middle Width (ft) : 20.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 10.000
Lower Width Left (ft) : 10.000
Lower Sideslope Right (z) : 10.000
Lower Width Right (ft) : 20.000
Mannings n : 0.040
Base Width (ft) : 5.0
Elevation (ft) : 141.30
Channel Slope (ft/ft) : 0.045
Channel Length (ft) : 7212.0

----------Right Overbank
Upper Sideslope (z) : 5.000
Upper Width (ft) : 5.000
Middle Sideslope (z) : 2.000
Middle Width (ft) : 20.000
Mannings n : 0.060

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

Link Name: XS-E
Link Type: Open Channel
Downstream Link Name: XS-B

----------Left Overbank
Upper Sideslope (z) : 2.000
Upper Width (ft) : 20.000
Middle Sideslope (z) : 3.000
Middle Width (ft) : 10.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 20.000
Lower Width Left (ft) : 5.000
Lower Sideslope Right (z) : 10.000
Lower Width Right (ft) : 10.000
Mannings n : 0.040
Base Width (ft) : 5.0
Elevation (ft) : 126.00
Channel Slope (ft/ft) : 0.091
Channel Length (ft) : 3537.0

----------Right Overbank
Upper Sideslope (z) : 100.000
Upper Width (ft) : 10.000
Middle Sideslope (z) : 2.000

Middle Width (ft) : 6.000
Mannings n : 0.040

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: XS-D
Link Type: Open Channel
Downstream Link Name: XS-B

----------Left Overbank
Upper Sideslope (z) : 4.000
Upper Width (ft) : 40.000
Middle Sideslope (z) : 5.000
Middle Width (ft) : 10.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 2.000
Lower Width Left (ft) : 5.000
Lower Sideslope Right (z) : 10.000
Lower Width Right (ft) : 5.000
Mannings n : 0.040
Base Width (ft) : 3.0
Elevation (ft) : 124.30
Channel Slope (ft/ft) : 0.069
Channel Length (ft) : 5004.0

----------Right Overbank
Upper Sideslope (z) : 2.000
Upper Width (ft) : 5.000
Middle Sideslope (z) : 3.000
Middle Width (ft) : 25.000
Mannings n : 0.060

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: POC
Link Type: Open Channel
Downstream Link: None

----------Left Overbank
Upper Sideslope (z) : 0.500
Upper Width (ft) : 3.000
Middle Sideslope (z) : 10.000
Middle Width (ft) : 10.000
Mannings n : 0.040

----------Main Channel
Lower Sideslope Left (z) : 0.500
Lower Width Left (ft) : 3.000
Lower Sideslope Right (z) : 0.500
Lower Width Right (ft) : 3.000
Mannings n : 0.024
Base Width (ft) : 10.0
Elevation (ft) : 100.00
Channel Slope (ft/ft) : 0.020
Channel Length (ft) : 1000.0

----------Right Overbank
Upper Sideslope (z) : 0.500
Upper Width (ft) : 3.000
Middle Sideslope (z) : 10.000
Middle Width (ft) : 10.000
Mannings n : 0.040

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: XS-A
Link Type: Open Channel
Downstream Link Name: POC

----------Left Overbank
Upper Sideslope (z) : 100.000
Upper Width (ft) : 25.000
Middle Sideslope (z) : 8.000
Middle Width (ft) : 40.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 2.500
Lower Width Left (ft) : 10.000
Lower Sideslope Right (z) : 4.000
Lower Width Right (ft) : 20.000
Mannings n : 0.040
Base Width (ft) : 10.0
Elevation (ft) : 80.00
Channel Slope (ft/ft) : 0.078
Channel Length (ft) : 2426.0

----------Right Overbank
Upper Sideslope (z) : 2.000
Upper Width (ft) : 4.000
Middle Sideslope (z) : 100.000
Middle Width (ft) : 40.000
Mannings n : 0.060

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: XS-C
Link Type: Open Channel
Downstream Link Name: POC

----------Left Overbank
Upper Sideslope (z) : 10.000
Upper Width (ft) : 5.000
Middle Sideslope (z) : 2.000
Middle Width (ft) : 20.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 5.000
Lower Width Left (ft) : 7.000
Lower Sideslope Right (z) : 5.000
Lower Width Right (ft) : 5.000
Mannings n : 0.040
Base Width (ft) : 3.0

Elevation (ft) : 75.80
Channel Slope (ft/ft) : 0.087
Channel Length (ft) : 2150.0

----------Right Overbank
Upper Sideslope (z) : 4.000
Upper Width (ft) : 25.000
Middle Sideslope (z) : 5.000
Middle Width (ft) : 5.000
Mannings n : 0.060

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

--
Link Name: XS-B
Link Type: Open Channel
Downstream Link Name: POC

----------Left Overbank
Upper Sideslope (z) : 3.000
Upper Width (ft) : 60.000
Middle Sideslope (z) : 10.000
Middle Width (ft) : 10.000
Mannings n : 0.060

----------Main Channel
Lower Sideslope Left (z) : 3.000
Lower Width Left (ft) : 5.000
Lower Sideslope Right (z) : 3.000
Lower Width Right (ft) : 8.000
Mannings n : 0.040
Base Width (ft) : 5.0
Elevation (ft) : 64.90
Channel Slope (ft/ft) : 0.033
Channel Length (ft) : 1713.0

----------Right Overbank
Upper Sideslope (z) : 4.000
Upper Width (ft) : 40.000
Middle Sideslope (z) : 100.000
Middle Width (ft) : 10.000
Mannings n : 0.060

Hydraulic Conductivity (in/hr) : 0.0
Massmann Regression Used to Estimate Hydralic Gradient
Depth to Water Table (ft) : 100.0
Bio-Fouling Potential : Low
Maintenance : Average or Better

**********************FLOOD FREQUENCY AND DURATION STATISTICS*******************

---------------------SCENARIO: 990395-SA1
Number of Subbasins: 1
Number of Links: 0

---------------------SCENARIO: 990395-SA2
Number of Subbasins: 6
Number of Links: 7

********** Link: POC ********** Link Outflow 1 Frequency Stats
Flood Frequency Data(cfs)
(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	6.853
5-Year	15.050
10-Year	23.689
25-Year	32.894
50-Year	36.949
100-Year	41.501
200-Year	42.222
500-Year	43.054

*************Groundwater Recharge Summary ***************

Recharge is computed as input to Perlnd Groundwater Plus Infiltration in Structures

Total Predeveloped Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: 990395	85411.390
Total:	85411.390

Total Post Developed Recharge During Simulation

Model Element	Recharge Amount (ac-ft)
Subbasin: 990395D	19827.110
Subbasin: 990395E	7683.208
Subbasin: 990395F	38500.000
Subbasin: 990395B	5178.226
Subbasin: 990395A	8929.596
Subbasin: 990395C	5293.226
Link: XS-F	Not Computed
Link: XS-E	Not Computed
Link: XS-D	Not Computed
Link: POC	0.000
Link: XS-A	Not Computed
Link: XS-C	Not Computed
Link: XS-B	Not Computed
Total:	85411.360

Total Predevelopment Recharge is Greater than Post Developed
Average Recharge Per Year, (Number of Years= 158)
Predeveloped: 540.578 ac-ft/year, Post Developed: 540.578 ac-ft/year

*************Water Quality Facility Data ***************

---------------------SCENARIO: 990395-SA1

Number of Links: 0

---------------------SCENARIO: 990395-SA2

Number of Links: 7

********** Link: POC **********

2-Year Discharge Rate : 6.853 cfs

15-Minute Timestep, Water Quality Treatment Design Discharge
On-line Design Discharge Rate (91% Exceedance): 6.99 cfs
Off-line Design Discharge Rate (91% Exceedance): 3.31 cfs

Infiltration/Filtration Statistics--------------------
Inflow Volume (ac-ft): 9861.78

Inflow Volume Including PPT-Evap (ac-ft): 9861.78
Total Runoff Infiltrated (ac-ft): 0.00, 0.00%
Total Runoff Filtered (ac-ft): 0.00, 0.00%
Primary Outflow To Downstream System (ac-ft): 9877.41
Secondary Outflow To Downstream System (ac-ft): 0.00
Volume Lost to ET (ac-ft): 0.00
Percent Treated (Infiltrated+Filtered+ET)/Total Volume: 0.00%

**************Compliance Point Results ***************

Scenario 990395-SA1 Compliance Subbasin: 990395

Scenario 990395-SA2 Compliance Link: POC

***** Point of Compliance Flow Frequency Data *****
Recurrence Interval Computed Using Gringorten Plotting Position

Predevelopment Runoff		Postdevelopment Runoff	
Tr (Years)	Discharge (cfs)	Tr (Years)	Discharge (cfs)
2-Year	9.484	2-Year	6.937
5-Year	22.158	5-Year	15.204
10-Year	31.986	10-Year	23.996
25-Year	45.591	25-Year	33.211
50-Year	46.850	50-Year	37.521
100-Year	50.201	100-Year	42.312
200-Year	57.717	200-Year	42.757
500-Year	67.745	500-Year	43.208

** Record too Short to Compute Peak Discharge for These Recurrence Intervals

****** Flow Duration Performance ******

Excursion at Predeveloped 50%Q2 (Must be Less Than or Equal to 0%):	-7.1%	PASS
Maximum Excursion from 50%Q2 to Q2 (Must be Less Than or Equal to 0%):	-7.1%	PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):	-11.1%	PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):	0.0%	PASS

MEETS ALL FLOW DURATION DESIGN CRITERIA: PASS

****** LID Duration Performance ******

Excursion at Predeveloped 8%Q2 (Must be Less Than 0%):	1.9%	FAIL
Maximum Excursion from 8%Q2 to 50%Q2 (Must be Less Than 0%):	0.2%	FAIL

LID DURATION DESIGN CRITERIA: FAIL

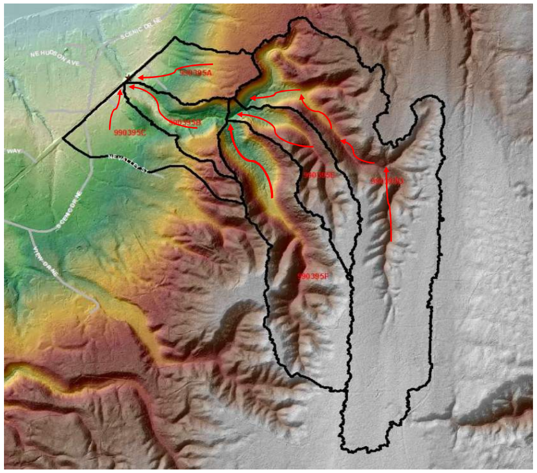
Jacobs

JOB TITLE:	CLIENT: WSDOT			DATE:	9/23/2022
	WSDOT NW Region Fish Passage - PHD - 990395 Spring Creek to Hood Canal	BW, EIT		JOB # :	A.P3.EV.990395-2-2-2
SUBJECT:	Hydrology	TJ, PE		Sheet # :	1 of 2
Topic:	Overview and QC Comments				

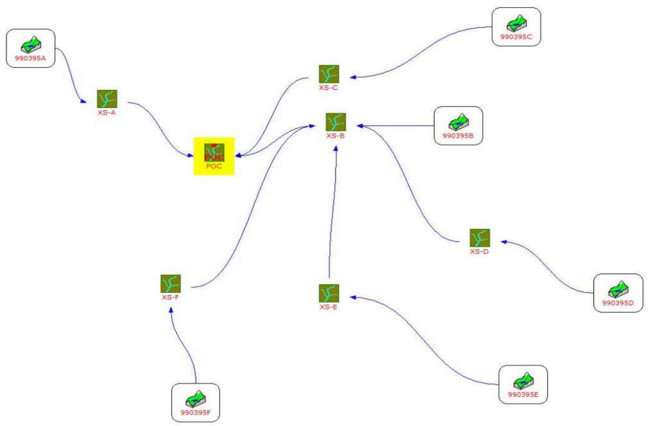
1.0 Final Results

SA-4 MGS Flood Input												
MGS Classifications	Subbasin A		Subbasin B		Subbasin C		Subbasin D		Subbasin E		Subbasin F	
	Area (Ac)	Percent Total	Area (Ac)	Percent Total	Area (Ac)	Percent Total	Area (Ac)	Percent Total	Area (Ac)	Percent Total	Area (Ac)	Percent Total
A/B Forest, Flat	1.9	4.4%	0.5	2.1%	0.3	1.1%	0.7	0.8%	0.3	0.9%	5.6	3.0%
A/B Forest, Mod	5.9	13.6%	3.3	14.3%	2.0	7.6%	3.8	4.2%	1.7	4.6%	14.7	7.8%
A/B Forest, Steep	10.6	24.3%	16.4	71.1%	4.3	16.2%	62.8	68.9%	20.6	56.7%	70.6	37.7%
A/B Pasture, Flat	0.2	0.4%		0.0%		0.0%		0.0%		0.0%		0.0%
A/B Pasture, Mod	0.3	0.6%		0.0%		0.0%		0.0%		0.0%		0.0%
A/B Pasture, Steep	0.0	0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
A/B Lawn, Flat	3.0	6.8%	0.0	0.1%	0.2	0.7%	0.0	0.0%		0.0%	0.0	0.0%
A/B Lawn, Mod	3.5	8.0%	0.2	0.7%	1.6	5.9%	0.1	0.1%		0.0%	0.0	0.0%
A/B Lawn, Steep	1.7	3.8%	0.6	2.4%	2.9	10.8%	0.4	0.4%		0.0%	0.2	0.1%
C Forest, Flat		0.0%	0.0	0.0%	0.2	0.7%		0.0%		0.0%		0.0%
C Forest, Mod		0.0%	0.0	0.1%	0.6	2.1%		0.0%		0.0%		0.0%
C Forest, Steep		0.0%	0.5	2.0%	0.5	2.0%		0.0%		0.0%		0.0%
C Pasture, Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
C Pasture, Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
C Pasture, Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
C Lawn, Flat		0.0%	0.0	0.0%	0.2	0.7%		0.0%		0.0%		0.0%
C Lawn, Mod		0.0%	0.0	0.1%	0.4	1.4%		0.0%		0.0%		0.0%
C Lawn, Steep		0.0%	0.2	0.7%	0.4	1.3%		0.0%		0.0%		0.0%
SAT Forest, Flat	0.9	2.1%	0.0	0.2%	0.9	3.5%	2.8	3.1%	1.4	3.8%	21.2	11.3%
SAT Forest, Mod	3.7	8.5%	0.3	1.2%	4.8	18.0%	7.1	7.8%	4.0	11.1%	44.8	23.9%
SAT Forest, Steep	2.0	4.5%	1.0	4.5%	4.2	15.5%	13.5	14.8%	8.3	22.9%	24.1	12.9%
SAT Pasture, Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
SAT Pasture, Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
SAT Pasture, Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
SAT Lawn, Flat	1.3	3.1%		0.0%	0.0	0.1%		0.0%		0.0%	0.2	0.1%
SAT Lawn, Mod	3.3	7.5%		0.0%	0.6	2.4%		0.0%		0.0%	1.7	0.9%
SAT Lawn, Steep	1.1	2.6%		0.0%	1.1	4.0%		0.0%		0.0%	4.4	2.4%
Green Roof		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Roads/Flat	1.5	3.5%	0.0	0.0%	0.1	0.4%		0.0%		0.0%		0.0%
Roads/Mod	2.0	4.6%	0.0	0.1%	0.4	1.4%		0.0%		0.0%		0.0%
Road/Steep	0.7	1.6%	0.1	0.4%	1.1	4.0%		0.0%		0.0%		0.0%
Rooftop/Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Rooftop/Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Rooftop/Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Driveway/Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Driveway/Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Driveway/Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Sidewalk/Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Sidewalk/Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Sidewalk/Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Parking/Flat		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Parking/Mod		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Parking/Steep		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
Pond		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
	43.6	100.0%	23.1	100.0%	26.8	100.0%	91.2	100.0%	36.4	100.0%	187.4	100.0%

SA-4 MGS Flood Results		
Exceedance Probability	Tr	*15-minute model timestep*
		Discharge (cfs)
0.5	2-Year	6.9
0.2	5-Year	15.2
0.1	10-Year	24.0
0.04	25-Year	33.2
0.02	50-Year	37.5
0.01	100-Year	42.3
0.005	200-Year	42.8
0.002	500-Year	43.2



Subbasin Sections						
Parameter	Basin A	Basin B	Basin C	Basin D	Basin E	Basin F
Left Overbank						
Upper Side Slope	0	3	10	4	2	2
Upper Width	25	60	5	40	20	20
Middle Side Slope	8	10	2	5	3	2
Middle Width	40	10	20	10	10	20
n	0.06	0.06	0.06	0.06	0.06	0.06
Main Channel						
Lower Side Slope Left	2.5	3	5	2	20	10
Lower Width Left	10	5	7	5	5	10
Lower SideSlope Right	4	3	5	10	10	10
Lower Width Right	20	8	5	5	10	20
n	0.04	0.04	0.04	0.04	0.04	0.04
base width	10	5	3	3	5	5
base elevation	80	64.9	75.8	124.3	126	141.3
channel bed slope	0.078	0.033	0.087	0.069	0.091	0.045
Head Elevation	270.1	121.5	264	469	447.7	462.6
channel length	2426	1713	2158	5004	3537	7212
Right Overbank						
Upper Side Slope	2	4	4	2	0	5
Upper Width	4	40	25	5	10	5
Middle Side Slope	0	0	5	3	2	2
Middle Width	40	10	5	25	6	20
n	0.06	0.06	0.06	0.06	0.06	0.06



2.0 Climate Change Impact

Climate Change Impact Analysis					
Exceedance Probability	TR	Climate Change Adjustment for 2040 (mean)	Predicted Flow for 2040	Climate Change Adjustment for 2080 (mean)	Predicted Flow for 2080
		%	Discharge (cfs)	%	Discharge (cfs)
0.01	100-year	28.1%	54.19911	44.1%	60.96871

Jacobs	CLIENT:	WSDOT		DATE:	5/15/2022
JOB TITLE:	WSDOT PHDs - 990395 Spring Creek Hydrology	BY:	BW, EIT	JOB # :	W3Y05003
SUBJECT:	USGS Regression Equations	CHECKED:	TJ, PE	Sheet # :	1 of 1

Topic: USGS Regression Method - Unnamed Tributary to Kinman
from: https://pubs.usgs.gov/sir/2016/5118/sir20165118_floodqtools.xlsm
documentation: https://pubs.er.usgs.gov/publication/sir20165118

Flood Q Regression Tool. Use to estimate flood discharge in Washington State at ungaged sites based on regional regression equations and user-determined basin characteristics.

DA = Drainage Area, in square miles; P = Average Basin Annual Precipitation, in inches (from PRISM data set, years 1981-2010); CAN = Percent canopy cover (NLCD 2001); AEP = Annual Exceedance Probability; Qu = Flood Discharge, in cubic feet per second at ungaged site for the indicated AEP; PI_L, PI_U= Predition Intervals (L=Lower and U=Upper)

Instructions for using the Flood Q Tool to estimate Flood Discharges at Ungaged Sites using the regional regression equations

Steps	Instructions
1	Select the Regression Region below from the List Box
2	Determine the drainage area, *DA* and the Annual Precipitation, *P* for the ungage drainage basin. If you pick Regression Region 1 or 2, determine the percent canopy cover, *CAN*.
3	Enter these basin characteristic values in the green-shade cells. If the cell changes to red, than the value is outside the range of valid values for this regression. Valid value range listed to the right of the green cells.
4	Rows 23-30 will have the results. Estimated flood discharge, Qu, will be found in column O and the 90% prediction limits for these flood discharges will be found in columns R and T.

Regression Region 1
Regression Region 2
Regression Region 3
Regression Region 4

User determined basin characteristics for ungaged site

Selected Region:		Regression Region 3		Range of values that are valid for the regression
Drainage Area, *DA*	=	0.638225	square miles	0.08 - 2605
Annual Precipitation, *P*	=	36.50	inches	33.29 - 168.0
Percent Canopy, *CAN*	=	91	%	value not used in regression

Selected Region: Regression Region 3

Estimate of indicated flood discharge for Regression Region 3 using regional regression equations

AEP		*Q_u, ft³/s	Prediction Intervals, 90% confidence level: PI_L, in ft³/s	PI_U, in ft³/s
0.5	=	10.6	5.3	21.3
0.2	=	17.1	8.3	35.2
0.1	=	21.6	10.3	45.1
0.04	=	27.5	12.6	59.9
0.02	=	31.9	14.2	71.7
0.01	=	36.7	16.0	84.2
0.005	=	41.4	17.4	98.8
0.002	=	48.1	19.3	120.1

*rounded to 3 significant figures

Regression Regions in Washington State